

"COGNITIVE" LEARNING IN THE ABSENCE OF COMPETITION OF INCENTIVES

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Received August 16, 1948

In a previous study (3) we have reported the results of a repetition of the Spence and Lippitt experiment (4) on latent learning in the T-maze.

In that investigation it was found that rats which are run in a single unit T-maze under conditions of satiation for both food and water can set up, at least at the descriptive level, "cognitions" as to the location of these two incentives in the two goal boxes of the maze. Further study of the animals' behavior led to an interpretation of the cognitions in terms of reinforcement theory, the details of which may be found in the original paper. Several sorts of reinforcements were assumed to be operating in the original experiment, among them being a direct reinforcing effect of seeing, feeling, and smelling the food and water even though there was no drive present (or, more precisely, no drive of sufficient strength to result in consummatory responses with respect to these incentives). It is not entirely clear from the discussion of Hull's Postulate 4 given in his *Principles* (2, p. 178) whether the secondary reinforcing effect which has been acquired by an object such as food is assumed to operate to increase habit strength even though the underlying drive is currently satiated. The use of Postulate 4 which we made in the publication cited was based upon a literal interpretation, since the postulate does not make any reference to the necessity for having a state of drive at the time of administering the secondary reinforcement. Once a stimulus or "state of affairs" has acquired secondary reinforcing powers by its temporal contiguity with drive reduction, these powers may be retained even though the original drive is no longer present. It is obvious that one could recognize the reality of secondary reinforcing effects without interpreting the postulate in this unrestricted way. That is, if the presentation of a certain visual stimulus were to be associated in the organism's history with reduction of hunger drive, any secondary reinforcing properties thus generated might exist only when the animal was hungry; it might still be assumed that reinforcement would occur through the mere presentation of this visual stimulus, even though the state of drive itself, though necessarily present, was not *reduced*. It is not profitable to argue about the various interpretations that may be put upon Hull's statement of Postulate 4 in the absence of any clear cut experimental evidence on the point. The purpose of the present experiment was partly to answer this simple question. If a rat runs a single unit T-maze while satiated for food and water, will the mere sight, smell, and touch of these incentives (goal objects) operate as secondary reinforcers? In the article cited, it was pointed out that it is impossible during the satiation phase of such a training series to establish that such reinforcing effects are taking place, since, if present at all, they are occurring in both goal boxes and hence a differential response strength cannot be observed. The appearance of appropriate behavior under the motivated conditions of the earlier experiment is of course subject to a diversity of theoretical interpretations and is incapable of giving a clear answer to this question. Furthermore, with drives such as thirst and hunger, it is unknown to what extent the drive stimuli are similar and to what extent there is an overlap in the afferent pattern produced by fractional consummatory responses associated with these drives. Recent work by W. T. Heron indicates that the whole question of "drive as a stimulus" is complicated when thirst is involved (1). There is the additional complication that these drives are not independently manipulable since a thirsty rat is always hungry in some degree. To avoid these complications one obvious solution is to perform an experiment under conditions of satiation in

which *both* of the incentives are found in the same goal box, whereas the goal box on the other side is empty. We must still assume various other reinforcing effects, but since these are presumably equal for the two sides, any reinforcing effect of finding food and water in one side but not in the other should show up in the form of a preference for the side containing these incentives. The development of phenomenological cognitions can also be studied in such a design uncomplicated by the problem of drive interaction and of drive discriminability.

APPARATUS, SUBJECTS, AND PROCEDURE

Subjects: The subjects of the present experiment were 30 albino male rats of the Sprague-Dawley strain, approximately 90 days of age, which had never been previously subjected to any experimental procedure.

Apparatus: The apparatus (3) was identical with that described in the previous paper: a single unit, tunnel-type, T-maze, one side of which was painted flat gray together with the adjacent half of the stem (floor and wall), the other side being painted flat black as was the adjacent portion of the stem. The animals were required to make a turn into the goal box in the same direction as the turn they had just previously made at the choice point. Retracing was prevented by the lowering of doors placed in the arms of the T.

Procedure: (a). *Test breaking and test for position habit:* After a test breaking stage, in which the rats were put into the maze three at a time and allowed to explore freely with no incentives present for one-half hour, there followed two days in which the rats were introduced singly for four runs per day, two of which were in immediate succession and two of which followed after about a half hour interval. These runs were all free and responses were recorded. After the second day the eight choices of each rat were studied and from an original group of 40 rats ten were eliminated on the basis of having shown the most pronounced position tendencies. The remaining 30 rats were divided into two groups of 15 each in such a manner as to equalize in several respects the position tendencies they had displayed in the eight free runs. The success of this matching may be indicated by the following data: For both groups the total number of left choices made in 120 runs (15 rats at 8 runs each) was 78. The total left choices in the last 90 runs came to 55 and 57, the total left choices in the last 60 runs to 38 and 39. The two groups were also equal (within one response) in the number of alternations on the first day, number of alternations on the second day, number taking the left side *first* on the second day, number with no right choices on the second day, number splitting their four choices equally on the second day, and number splitting three to one or one to three on the second day. As was true in the previous experiment, there was evidence of a rather strong left preference, i.e., to the darker side.

b. *Satiated runs:* Each rat was given two free runs per day for 14 days. Food and water were available in the home cages at all times during these runs, each cage being supplied with six large sticks of food thrown on the floor daily in addition to the food in the usual food container. Prior to running, each rat was put in a special feeding cage for five minutes in which, in addition to the usual water bottle and food box, a large saucer of water was placed on the floor, food sticks were lying about in the shavings, and a saucer filled with food broken into small pieces was also present in the cage. That these procedures resulted in a satiation for the incentives was attested by the fact that no rat ever ate or drank in the goal boxes.

The differential treatment of the two groups described above consisted only in the location of the food and water in the two goal boxes. For one group both food and water were found in the right goal box and no incentive was present in the left; for the other group these conditions were reversed. The incentives were placed in the goal box so as to minimize the likelihood that an animal could enter the goal box and remain there for any length of time without having some perception of their presence. Water was present both in the nozzle of a water bottle of the type found in their feeding cages, as well as in a small tin cup attached to the floor. More pieces of food were heaped about the water container, and

in addition several larger pieces were placed so as to extend farther toward the junction of the arm and goal box. Animals were removed from the goal box 30 seconds after entrance.

c. *Motivated "test" trial*: After these 28 runs under satiated conditions each rat was given a single trial after having been deprived of both food and water in the home cage for approximately 30 hours. The results of this trial should give further evidence on the acquisition of "cognitions" uncomplicated by the involvement of drive interaction and discriminability.

RESULTS

At the beginning of the satiation runs of the experiment (Part b), we have two groups of rats which have been matched by numerous criteria for the strength of the position tendencies. Two questions can be asked. First, what evidence of the establishment of cognitions will appear after 28 such cognition experiences? Secondly, is there evidence of a secondary reinforcing effect of perceiving the two incentives, even in the absence of relevant drive? The first question is to be answered by a comparison of the number of left-going responses for the two groups on the "test" (motivated) trial. The second question is to be answered directly by comparison of the day-by-day frequency of the left versus right choices for the two groups now running under satiated conditions.

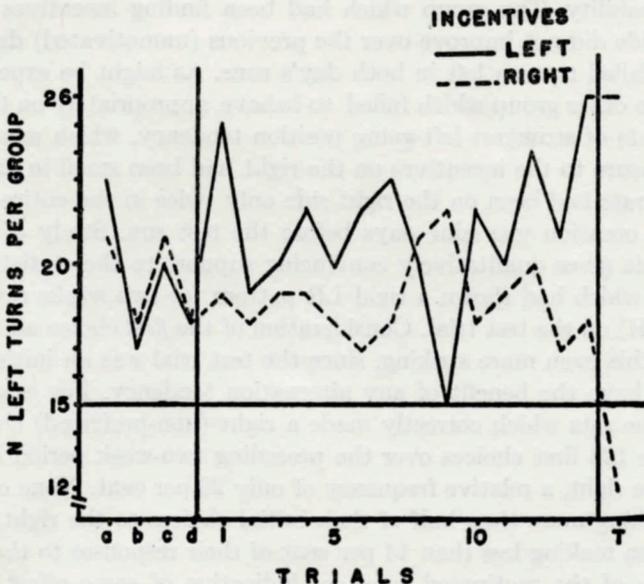


FIG. 1. Total Number of Left Turns for Each of the Two Groups of Rats (15 rats per group; two runs per rat per day). Trials a, b, c, d were pretest runs with no incentives present; days 1-14 were two free runs with incentives present as indicated in the legend, rats satiated; trial T is a single cognition test trial, with all rats deprived of food and water, pro-rated as indicated in the text.

The results are presented in the accompanying figure. The two points on this graph indicating the results of the motivated runs (15th day) are pro-rated values. That is, since on this day each rat was run only once, to make the ordinate

unit comparable to the preceding curve the number of left choices has been multiplied by a factor of two.

As can be seen from the curves, on the motivated trial there is rather clear-cut evidence of "appropriate" behavior in terms of the position of the incentives. Of the 15 rats which had been finding food and water on the left side during the satiated runs, 13 or 86.7 per cent went to the left. Of the 15 which had been finding food and water on the right side, 9 or 60.0 per cent went to the right. It should be noted in connection with this second percentage that this was the first of 18 days on which either group made over half of their responses to the right (brighter, non-preferred) side. The second group of rats had made a total of only 37.4 per cent right choices during the satiated runs. Since $np = 9.45 > 5$, we can use normal curve tables in evaluating the significance of difference in proportion of left choices (Kenney, II, p. 120). Applying the usual t test to this difference, we have

$$t = \frac{p_1 - p_2}{\text{S. E. diff.}} = \frac{.867 - .400}{.176} = 2.69$$

This difference in the proportions is significant at better than the 1 per cent level of probability. The group which had been finding incentives on the left (preferred) side did not improve over the previous (unmotivated) day, only two rats having failed to turn left in both day's runs. As might be expected, of the six rats in the other group which failed to behave appropriately on the test trial three were rats of strongest left-going position tendency, which meant that the satiated exposure to the incentives on the right had been small in amount, e.g., one of these rats had been on the right side only twice in the entire two weeks, and the last occasion was nine days before the test run. Study of records for individual rats gives qualitatively convincing support to the statistics. For example, a rat which had shown a rigid LR pattern for two weeks responded appropriately (R) on the test trial. Consideration of the *first* choice on the satiated days makes this even more striking, since the test trial was an initial day's run and did not have the benefit of any alternation tendency. For example, if we study the nine rats which correctly made a right (non-preferred) choice on the test trial, the 126 first choices over the preceding two-week period had yielded only 25 to the right, a relative frequency of only 20 per cent. None of these rats had been making more than half of their initial choices to the right, and six of them had been making less than 14 per cent of their responses to the right.

The results of the motivated runs are indicative of some effect of running under satiated conditions and hence suggest the establishment of cognitions in the descriptive sense of that term. But it is interesting to note that in spite of some disturbing irregularities in the curve, the graph suggests a *tendency to differential response during the satiated runs*. In the satiation period of 14 days 12 days show a greater number of left-going choices by the group that found food and water on the left side than by the other group. Applying the very

simple test of significance suggested by this fact, we find that the chance probability of such an asymmetry in the number of "superior" days for one group is less than 1 per cent. A more rigorous way of analyzing the same data is to determine the significance of the difference in total proportion of left-going runs for all of the 840 trials during the satiation period, i.e. for the two trials for each of 15 rats in each of two groups on each of 14 days. The group which was finding food and water on the left side made a total of 299 left-going responses out of 420 runs, or 71.2 per cent left. The group that was finding food and water on the right side made a total of 263 left-going responses or 62.6 per cent left. The difference between these percentages, while small, is significant at the 1 per cent level of probability. It should be pointed out that this test is too rigorous since the denominator is based upon the assumption of independent trials. Since the rats were run for two trials per day and most of them showed definite alternating tendencies, this leads to a marked overestimation of the standard error and hence an underestimation of the significance. A third test of the separation of these two curves is the *t*-test for significance of difference of means of paired variates for all 14 of the training days. The mean difference in the number of left-going runs between the two groups over 14 days is 2.57 and the standard error of this difference using the paired variates formula is .96, yielding a $t = 2.67$ which with 13 d.f. is significant at the 2 per cent level of probability. We are not prepared to account for the rather pronounced reversal of this trend on the ninth day, but neither it nor the correspondingly large difference shown on the first day are statistically significant ($.10 > P > .05$). It is interesting to speculate as to whether the spike seen on the first day might be demonstrated, with larger groups and in the absence of a strong position tendency, to be a real effect. If so, one might think in terms of an "extinction" of the secondary reinforcing effect of coming upon food in the maze, because the animal is not hungry and hence the secondary reinforcing effect of the complex pattern "food-in-goal-box" undergoes a decrement. This extinction is not strongly generalized to "food-in-home-cage," and it may be only weakly counteracted by the generalized secondary reinforcing effect of the latter (which is of course periodically reinforced by primary drive reduction).

Study of individual records in relation to the day-by-day trend shows this difference was not the result of exceptionally rigid position habits on the part of a few rats. In fact, the two rats showing the most rigid position tendency were working in opposition to the general finding, and actually made more left-going responses than any of the rats which were finding the incentives on the left. But the distribution of all rats by total left choices in 28 trials (not reproduced here) shows that only 20 per cent of the right-going group reaches or exceeds the median number of left choices made by the left-going group; and only 13 per cent of the latter group fall at or below the median of the former.

It seems very likely that there was a tendency for the two groups to respond differentially to the two sides, presumably as a function of the only factor which systematically differed, namely the presence of the "unwanted" incentive. It is

suggested that the separation of these two curves might have been more consistent and greater in amount had the complicating effect of the position tendency not been present, since the curve which fails to show a clear trend in the expected direction is that for the group finding the incentive on the non-preferred side.

DISCUSSION

The present data show rather clearly the effect of exposing satiated rats to the location of food and water upon choice behavior when animals are subsequently motivated. In this sense the evidence for "cognitions" acquired by experiences while satiated is somewhat clearer than was the case in the original experiment. However, the latent learning demonstrated by this finding is not unequivocally "latent," since there is evidence for a differential response tendency during the satiated period itself. This latter finding implies that Hull's Postulate 4 should probably be taken quite literally as stated in the *Principles of Behavior*. Once a stimulus has acquired secondary reinforcing properties through its contiguity with reduction of any drive, these secondary reinforcing properties continue to operate to some extent even when that particular drive is not present. Habit strength thus accumulated is then available for multiplication by all drives (including the drive used to generate secondary reinforcing properties) when it again becomes of sufficient strength. The way in which such a situation could result in special instances of latent learning can be made clear with the present experiment as a paradigm. Suppose a rat is satiated for both food and water, has explored a certain apparatus sufficiently and is relatively free of anxiety. Assume that under these conditions the combined effect of the sex drive, social-gregarious needs, activity drive, and the drive to escape from the maze are able to furnish, say, 20 motes of motivation. Assume further that the upper limit of habit strength which can be produced by the presentation of food and water when the animal is in a satiated condition to be 15 habits. Whatever habit strength is produced by reinforcing effects of removal from the goal box and return to the home cage is equal for the two sides, so that there is built up a difference of approximately 15 habits between the left and right-going reaction. Assume that the standard deviation of behavior oscillation function is 10 wats. Then the standard deviation of the difference between right and left-going effective reaction potentials in wats over series of trials is equal to the $\sqrt{10^2 + 10^2} = 14$. When satiated, the ratio of the mean wat difference for the two sides to the standard deviation of the behavior oscillation function is $.20 \times 15 \times \frac{1}{14} = .2$. At .2 of a standard deviation, the per cent of correct responses is about 58 or 8 per cent better than chance. Now suppose the rat is put under a 24-hour thirst and hunger drive. Assume this raises the drive level to 60 motes. The new value of the standard score on the behavior oscillation function then becomes $.60 \times 15 \times \frac{1}{14} = .6$. At .6 of a standard deviation, the per cent of correct responses is about 73, or 23 per cent better than chance. Such a set of conditions could readily yield our results which were 8.6 per cent and 23.3 per cent above chance under the two conditions. It is obvious from this example that under appropriate con-

ditions of satiation, rather slight differences in habit strength could be accumulated which would not appear statistically except under scrutiny of a tremendously large number of trials. But since the proportion of correct responses is a function of reaction potential, even a fairly slight difference in habit strength may show up as a significant differential response tendency when sufficient motivation is applied as a multiplying factor to the habit difference. It is of course assumed in this sort of development that the standard deviation of the behavior oscillation function is more or less invariant with drive, which may ultimately turn out to be untrue. These considerations apply, of course, only to that variety of latent learning in which the incentive is present but the organism is unmotivated for it.

The implications of such an interpretation of Postulate 4 for the issue between cognitive and S-R interpretations of learning will not be discussed in detail here. It is obvious that if the exposure of the organism's receptors to an object which has been drive reducing exerts a feeble but nonetheless demonstrable reinforcing effect, the possibilities for the conditioning (under satiated conditions) of various orienting and goal responses are always available. It might seem that such an interpretation makes negligible any difference between Tolman's "cognitions" and the "responses" of S-R theory. To be sure, the secondary reinforcing effect of the perceived object is presumed to remain in the long run dependent upon primary drive reduction. But cognitive theory surely assumes that what has been a "goal" object can be systematically deprived of its character as such, in which case the cognition theorist would be led to the same predictions as the reinforcement theorist. Hull's fractional consummatory responses, elicited by the presence of the food and then conditioned to internal and external stimuli by the momentarily drive-independent secondary reinforcing effect of the food, would then become simply a slightly more molecular mechanism for what are called at the phenomenal level "cognitions."

A real (non-verbal) difference still remains, however. The present use of S-R reinforcement theory implies that although slight, the difference in habit strength is already being produced, since it is responses that are strengthened, not "knowledge." Therefore a delicate enough apparatus and a large number of organisms must always show a difference during the latent period, such as here obtained. Cognitive theories do not require that such an effect should be detectable. Only if a cognition theorist should add that the animals probably "like to take a look at what may come in handy sometime" would the difference between the theories become a metaphysical one.

SUMMARY

The main findings of the present study are two:

1. When both food and water are placed in the same goal box to avoid the problem of drive competition and drive interaction, animals which run a T-maze under satiated conditions show evidence of learning the location of these incentives when they are later motivated.

2. The significance of this result for a decision between cognition and S-R theories is lessened by the fact that there appears to be a significant preference for the side on which the incentive is found even during the satiated runs. It appears that the secondary reinforcing effect of food and water as incentives is at least in some degree dissociated from the primary drives.

REFERENCES

1. HERON, W. T.: Internal stimuli and learning. *J. comp. physiol. Psychol.*, 1949 (in Press).
2. HULL, C. L.: *Principles of Behavior*. New York: Appleton-Century, 1943.
3. MEEHL, P. E. AND MACCORQUODALE, K.: A further study of latent learning in the T-maze. *J. comp. physiol. Psychol.*, 1948, **41**, 372-396.
4. SPENCE, K. W. AND LIPPITT, R.: 'Latent' learning of a simple maze problem with relevant needs satiated. *Psychol. Bull.*, 1940, **37**, 429.