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# Latent Learning as a Function of Exploration Time

Gary France
*Central Washington University*

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# LATENT LEARNING AS A
# FUNCTION OF EXPLORATION TIME

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by
Gary France
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J. J. Crawford, COMMITTEE CHAIRMAN

Thomas B. Collins, Jr.

Gerald Gage

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# Latent Learning as a Function of Exploration Time

Gary France

Latent-learning experiments were designed to explore a type of behavior not adequately explained by reinforcement theory. As latent-learning designs have developed during the past thirty-five years, reinforcement theory has also developed, producing terms and concepts intended to explain latent-learning behavior. The present experiment includes (a) an effort to control extra-goal-box cues--a variable that has been a source of difficulty in certain previous experiments--and (b) raise again the question of whether reinforcement theory adequately explains this type of behavior.

Clark Hull posited that learning does not occur without reinforcement (1943, p. 80; 1952, pp. 5, 6). In terms of reinforcement theory, reinforcement is "the rapid diminuation in the motivational stimulus" (Hull, 1952, p. 6). For example, stimuli resulting from deprivation of food presumably impinge on receptors of an animal deprived of food. When the animal receives food these stimuli are rapidly diminished. The rapid diminishing of these stimuli is reinforcement.

When such reinforcement is closely associated with an effector activity (taking a step, moving the head, or chewing food), and when this activity is closely associated with another stimulus (such as a red light, an intersection of a maze, or the smell of food), this latter stimulus will increase its tendency to evoke the response or effector activity.

Thus Hull (1952, pp. 5, 6) describes a process such as maze learning. A stimulus increases its tendency to evoke a response when they are closely associated with each other and with a reinforcer.

Hull's theory predicts that if a hungry rat is fed each time he runs a maze, the running time and the errors will decrease. In Hull's terms, the running of the maze is a series of responses to the stimuli from the maze, and connections between these stimuli and responses are strengthened by the reinforcing food. The maze performance is a habit which becomes stronger with the number of times it is reinforced. Learning would not occur without reinforcement.

Tolman, a cognitive theorist, disagreed with Hull's view. He explained latent learning by positing, not just an S-R connection but an $s_1r_1$--$s_2^+$ connection. The first stimulus may be the choice point of a T-maze. The response may be going to the right goal box, but the mode of response is not specific. The first stimulus may be followed by running one time, walking another, or crawling another time. The second stimulus may be a distinctive goal box. This triple connection becomes an expectancy or belief which might be described anthropomorphically, "When I see this choice point, if I turn right, I expect to see the white goal box." The plus value, valence, is determined by the "final values. . .and/or the terminal drive-stimulations" (1959, p. 125). For latent learning Tolman invoked a curiosity drive which accounts for a positive valence. In other types of experiments, food would account for a positive valence. A negative valence (shock) would serve equally well for learning the sequence of connections. Learning occurs, not only as a function of valences, but as a function of "frequency, recency, and distribution of trials" ("laws of 'Exercise'") as well. During unreinforced exploration the curiosity drive furnishes all the learned expectancies with positive valences. An $s_1r_1$--$s_2^+$ connection leads to an $s_2r_2$--$s_3^+$ connection. The rat also forms expectencies resulting from a <u>left</u> turn at the choice point. In total, exploration of the T-maze produces numerous sets, expectancies, or beliefs. These sets function something like a map in the rat's brain permitting it to respond in the appropriate direction with the appropriate mode of movement at the appropriate time. The rat learns that a right turn at this point leads to a white goal box, a left turn leads to a black box. Then if food is introduced into one of the boxes in the presence of the rat for the first time, the rat is capable of selecting the map-like set leading to the correct goal box.

Tolman wrote that "reinforcement *per se*" is not always necessary for learning (1949, p. 154). He agreed that the rat is "led as a result of . . . stimuli to the responses that actually occur" (1948, p. 192), but he did not agree that the rat responds "helplessly . . . to a succession of external stimuli" (p. 189). Tolman posited that the brain processes are far more complex than a series of simple connections, that the brain is "more like a map control room," and "that in the course of learning something like a field map of the environment gets established in the rat's brain" (p. 192). "Learning consists not in stimulus-response connections but in the building up in the nervous system of sets which function like cognitive maps" (p. 193). This theory describes learning without the presence of obvious reinforcement.

The following review describes the development of latent-learning experiments and the explanation of latent-learning behavior in terms of reinforcement theory. Fundamentally, latent learning is learning without reinforcement. More specifically, latent learning is said to have occurred when an animal, having been presented with certain complexes of nonreinforcing stimuli, will, when given incentive, manifest a new, specific, and predicted pattern of activity. The learned activity may have occurred previously in a random fashion, but it is "new" in that it is predictably manifest after the incentive.

The following review introduces an experiment designed to explore whether learning can occur without reinforcement.

## Five Types of Latent-Learning Experiments

MacCorquodale and Meehl (1954), following the pattern of an earlier work by Thistlethwaite (1951), reviewed latent-learning literature and classified the experiments into five types.

_Type 1_. Tolman credited Blodgett with originating both latent-learning experiments and the concept of latent learning itself (1948, p. 19; 1959, p. 149). Blodgett's original experiment (1929) provided the essential description for Type 1. He ran three groups of rats through a six-unit maze. He counted the errors of each rat, removed each rat from the maze when it reached the goal point, and returned it to its home cage. Group I was fed at the goal point each day for seven days. Group II was not fed except on the seventh, eighth, and ninth days. Group III was fed on the third through the seventh days. Group I, the control group, improved steadily and established an operant rate of learning. Groups II and III improved very slightly until they were fed, then they improved sharply and virtually matched the performance of Group I within one trial. Thus, the improvement (reduction of errors) rate of the experimental groups after they were fed were significantly better than any part of the operant rate established by Group I.

These results seemed to support the cognitive view that the feeding evoked responses which demonstrated learning that had occurred <u>before</u> the introduction of reinforcement. But this cognitive interpretation fails to explain the slight improvement by the experimental groups during this same period--before the introduction of food. The early improvement in performance, though slight, indicates the presence of a mild reinforcer before feeding was introduced. Hull simply posited that the experimental groups may have been rewarded during initial trials by a "mild . . . incentive such as a cage mate" (1952, p. 148), and with the introduction of a stronger reinforcer, Hull's system predicts a rapid improvement like that demonstrated by Blodgett. Therefore Type 1 experiments do not adequately demonstrate latent learning. An adequate latent learning design must account for the possible reinforcing effect of systematically removing the rats from the maze at the goal point and taking them to their home cages and cage-mates.

Type 2. Rats are permitted to explore a multi-unit maze. Later, when reinforcement is introduced, the rats are able to run the maze with significantly fewer cul entries than chance or control groups. MacCorquodale and Meehl (1954, p. 208; 1951) mention three experiments indicating that "rats, even before reinforcement is ever encountered, have developed dispositions to stay out of the culs during their free-exploration period."

Hilgard (1956, p. 211) suggests that this phenomenon of reducing cul entries is more complex than indicated by the observations of MacCorquodale and Meehl. He cites a later study by Kimball, Kimball and Weaver (1953) in which younger rats and a different width maze were used. In contrast to the studies cited by MacCorquodale and Meehl, this latter study found that Ss did not develop dispositions to stay out of the cul entries.

MacCorquodale and Meehl object to Type 2 studies in the face of evidence that Ss reduce cul entries before encountering reward. They reason that if reduction of cul entries is a function of some factor other than the food at the critical trial, behavior during the critical trial cannot be called "goal-seeking" or "correct."

Until further research isolates and controls the variables preceding reduction of cul entries in unreinforced exploration, a Type 2 experiment may be subject to such objections.

Type 3. In Type 3 experiments water is typically placed in one goal box of a T-maze and food in the other. Operationally satiated rats are run through the maze. Then the rats are deprived of food (or water) and learning is measured by their choices of appropriate goal boxes. MacCorquodale and Meehl (1954, p. 209) review seven positive and two negative studies.

Hull, writing of this type experiment, posited that the sight of food "mildly" evokes an antedating goal reaction, which, in turn, gives rise to its goal stimulus, which, having powers of secondary reinforcement (1952, pp. 14, 125), reinforces the stimulus trace of, for example, looking to the right to the response of moving to the right (p. 148). His subsequent Theorum 31 (p. 149) predicts positive results from Type 3 experiments.

Hull's fractional antedating goal reaction, $r_G$, is a goal response occurring earlier in a series of stimuli than the event corresponding to the original reinforcement. For example, a rat may lick its lips and make chewing movements while eating. These movements, associated with eating, are goal responses. If the rat is deprived of food, it may lick its lips or make chewing movements before food is presented to it. These goal responses antedate or anticipate the goal, food. These movements give rise to proprioceptive goal stimuli, $s_G$, which are mildly reinforcing.

Thus a rat exploring a maze may form a S-R connection if S and R are closely associated when the rat licks its lips ($r_G$) and is reinforced by the $s_G$ arising from this movement. These anticipatory goal reactions and the stimuli arising from them enable Hullians to explain behavior anthromorphically labeled "anticipation," "expectation," "foresight," and "cognition" (pp. 14, 108, 148, 150).

MacCorquodale and Meehl criticize this explanation for "the general vagueness of the $r_G$ construct as to the conditions of its strengthening, its role as <u>elicitor</u>, and, finally, its specification as to locus" (1954, p. 209). These writers see Types 3 and 5 as the most embarrassing to S-R-reinforcement theorists (pp. 209, 211).

<u>Type 4</u>. A rat is deprived of food and trained to run to one arm of a T-maze where he finds water. Then he is deprived of water and trained to run to the other arm to find food. Learning is measured by the rat's choice of an appropriate goal on a critical test run. As with all types of latent-learning experiments, considerable variation of design exists within Type 4, but the essential factor is that rats are trained with a goal object such as food in the presence of a strong, irrelevant, and competing drive such as thirst. Type 4 experiments tend to produce a greater proportion of negative results--MacCorquodale and Meehl rated seven out of eighteen as positive (1954, p. 210).

Type 4 experiments are of questionable value. Hull's positive prediction for Type 3 is equally applicable to Type 4. And the cognitive view can support a negative prediction! MacCorquodale and Meehl reason that from the cognitive view the "'emphasis' value" of an irrelevant goal object is "small . . . or even frustrating," and, under repeated trials, it may be "conducive to negative emotional conditioning" (1954, p. 210). Thus, with Hullians predicting positive results, and with a cognitive theorist able to predict negative results, Type 4 seems inappropriate to resolve the learning-without-reinforcement issue.

Type 5. Some Type 5 studies seem to have the most definitive design to test the possibility of learning without reinforcement. Rats are permitted to explore a T-maze with distinctive goal boxes. After the exploration periods learning is measured in a single critical trial. The rat, deprived of food, is introduced into one of the unlike goal boxes where it finds food for the first time. It is soon removed and placed at the starting point of the maze. If it chooses the appropriate route to the goal-box position, it is credited with having learned.

The MacCorquodale and Meehl review lists four positive and three negative Type 5 studies (1954, p. 211). Tolman and Gleitman (1949) were among those who obtained positive results. They used unlike goal boxes, but, instead of permitting exploration, they forced rats by closing gates to choose alternate goal boxes on successive training trials. The rats were reinforced with food on each training trial. Then each rat was shocked in a goal box and tested for avoiding that box in the critical test run. The use of food as a reinforcer during training makes the study inadequate for demonstrating learning without reinforcement. Another positive study listed by MacCorquodale and Meehl is that of Iwahara and Marx (1950), but it has never been published.

Gilchrist (1952) manipulated time and the presence of food during maze exploration. He reported that latent learning without food present was not significantly different from learning without the presence of obvious reinforcement. The fourth "positive" study is Seward's (1949). The present experiment essentially follows Seward's design, and a critical discussion of it will follow later.

Leeper (1935) failed to support the existence of latent learning. Over 32 days his rats accumulated 160 hours of exploration time in a maze with three differentiated goal boxes. The next day the goal boxes were moved to another part of the room. A rat was fed in one, watered in another, and allowed to explore the third for periods of 35, 20, and 35 minutes respectively. This process was repeated on the next two days. Learning was measured with five trials a day in the original three-box maze for six days under drives of hunger and thirst on alternate days. Negative results indicate the problem was too complex. The three-day interval between exploration and testing and the reinforcement of being fed in goal boxes in a new position for extended periods during the three-day interval do not produce latent-learning behavior in rats.

Denny and Davis (1951) produced negative results and posited that "the presence of some sort of 'potential reward' is necessary" during initial exploration. After giving their rats unreinforced exploration in a T-maze with differentiated goal boxes, and before the rats were tested for learning, the researchers gave 30 reinforced trials down an alley to a goal box. As in the Leeper work, negative results may have resulted from the complexity of the lengthy, reinforced trials associating the goal box with a new situation on a straight runway. Another variable contributing to negative results may have been inadequate differentiation between the goal boxes. One was flat white, the other flat black. Typical latent-learning designs use tactile as well as visual cues.

The final study with negative results listed by Mac Corquodale and Meehl is that of Seward, Datel, and Levy (1952). This study is composed of three latent-learning experiments. The first was considered "exploratory" (p. 275) by the authors. Only seven Ss were assigned to each group, and when the results "were complicated by avoidance behavior," they "decided to change the technique rather than add enough cases to justify statistical tests of significance" (pp. 276, 280). These results failed to indicate latent learning. In the second experiment Ss were fed at the critical tests but were delayed before being permitted to run their tests. "When tested about 20 minutes later they failed to demonstrate latent learning. Experiment III was similar but shortened the time between feeding and testing to a few seconds" (p. 280). Performance in the third experiment significantly indicated latent learning. Because the first two of these experiments produced negative results, MacCorquodale and Meehl listed the whole study as negative. The second and third experiments indicate that rats cannot solve the problem unless they are tested within seconds after being fed in one of the goal boxes.

Seward's 1949 Study. Seward, over a period of six days, gave his rats preliminary adaptation to a straight alley which included three runs to each of two unlike goal boxes (1949). On each of the next three days he provided a 30-minute exploration period of a T-maze with the two unlike boxes attached in such a fashion that the rats could not see the goal boxes from a choice point. The rats were fed one hour a day at 24-hour intervals, and they were never fed in the maze or alley. Cheesecloth, illuminated from the under side, was draped over wires 18 inches above the maze, covering the entire maze and preventing the rats from seeing beyond the cheesecloth.

On the test day a rat was permitted to explore the T-maze with its unlike goal boxes for three minutes, after which it was isolated for about 25 minutes. Then it was placed in one of the distinctive goal boxes with the door leading to the maze closed. The rat found food in the box, started to eat it, and was removed and placed in the starting position of the maze. Of 32 rats, 28 made the appropriate choice.

Following the main experiment, Seward ran three control experiments to test (a) whether preceding exploration was a necessary factor, (b) whether the rats depended "on cues not present at the choice point," and (c) whether choice depended "on the association of one set of these cues with the food," or on a "perseverative trace." The first and third control experiments supported Seward's position that the preceding exploration was a necessary factor preceding successful choices and that successful choices "depended not merely on a perseverative endbox trace but on an association of one endbox with food" (pp. 179, 183). Seward's second control experiment, however, did not support Seward's view. It indicated that successful runs in the main experiment *were* dependent on cues visible at the choice point (see Seward's terms after (b) above).

Seward described his concern that the rats would be guided to the goal box by cues visible at the choice point. He specified that his goal boxes were "out of sight from the choice point," that they were "projecting at right angles to the crossbar" of the T-maze, and that the test of his hypothesis "must depend on cues not present at the choice point." Seward spotted a portion of a lamp visible both from within the goal box (during feeding at the critical test) and at the choice point, and he wanted to rule out the possibility that this lamp became a stimulus equivalent to guide the rats from the choice point to the goal box.

Seward's second control study was an attempt to control this variable, but it produced negative results. The main experiment was repeated except that when Seward was ready to feed the rats in the goal box, he removed the box from the maze and placed it in front of the starting box so that it formed an extension of the starting box. He fed each rat in the newly positioned goal box, removed and detained the rat until the goal box could be replaced in its normal position on the maze, then started the rat in the T-maze. Thirty-six of the 48 rats were run with negative (chance) results, so, to reduce detention time between feeding and the critical test run, duplicate goal boxes were constructed.

One box was left in its normal position on the maze; the other was left in feeding position against the starting box. The last 12 rats also produced negative results. One rat tried to climb the back wall of the starting box, which may have indicated that the new location of the box produced conflicting cues to the rat.

Negative results indicated that the positive effect in the main experiment may have been due to failure to eliminate secondary reinforcers. Perhaps the rats in Seward's main experiment <u>did</u> use the lamp as a "stimulus equivalent" or secondary reinforcer to guide them--a possibility among others that Seward acknowledged. Hull (1952, p. 6) describes a secondary reinforcer as a stimulus in close conjunction with a reinforcing situation. The lamp was admittedly present while the rat was eating. Later, at the critical trial when the rat reached the choice point, the stimulus of the lamp was visible, and the rat ran to it. This, of course, destroys the latent-learning position which maintains that the correct choice can be made without the use of reinforcers. Until this variable is controlled, it may be inappropriate to list Seward's study as positive.

Of the five types of latent-learning experiments, Type 5 is the most useful for demonstrating learning without obvious reinforcement. Hull predicted positive results for Types 1, 3, and 4, because animals are offered food during, or are lifted out of the maze after training runs. He invoked a mild reinforcing effect from being returned to a cage mate or from the sight of food, which, with Hull's fractional antedating goal reaction, accounts for Blodgett's slight initial improvement as well as positive results in Types 3 and 4. In the Type 5 design the animals need never encounter food or water during exploration, and at the end of the exploration period they can be removed from the maze from whatever random position they happen to occupy at the time. The Type 2 design is not useful until more is known about the animals' developing a disposition to avoid cul entries. The Type 5 design permits use of a single-unit T-maze which avoids this problem.

## The Problem

Learning Without Reinforcement. With few exceptions the experiments described in the literature employed training trials or exploration periods in the presence of food or water or with the condition of removing the animal at the goal point. Most exceptions such as Leeper (1935), Denny and Davis (1951), and Seward's second control experiment (1949) produced negative results. Gilchrist's (1952) was positive. The present study was designed to supply more data indicating latent learning without these types of reinforcement.

*Control Seward's 1949 Study*. Seward's second control experiment failed to exclude the possibility that the rats in his main experiment used an extra-maze cue visible both from the choice point and from the feeding situation. Though his main experiment is usually listed as favoring latent learning, the fact remains that Seward himself saw the possibility of a secondary reinforcer functioning. The present experiment was an effort to replicate the essential nature of Seward's second control experiment. One critical variable, length of exploration time, was manipulated in an effort to explain Seward's negative results.

*'Misinforming' the Rats*. In Seward's and in the present study, latent learning was measured by counting the proportion of rats which ran from the starting point of the T-maze to the appropriate goal box during critical trials. Both reinforcement and cognitive theory posit that *S*s must be exposed to adequate stimuli before they can make that response, but Seward's whole point was to expose the *S*s to the stimuli without reinforcement. He attempted to eliminate the effect of reinforcement on positional stimuli by placing the goal box in a new, neutral position during feeding.

But moving the goal box during feeding introduced new problems. Any stimuli to which *S*s were exposed while feeding would be incompatible and would interfere with those to which he was exposed during exploration. Then if latent learning did occur during exploration, it would not be demonstrated because of the incompatibility of the stimuli. Kimble, analyzing Seward's work, wrote, "This procedure (which might be thought of as misinforming the rats as to the location of the food) leads to a failure of latent learning to appear" (1961, p. 230). Seward (1949, p. 181) and Thistlethwaite (1951, p. 105) both suggest that the failure of latent learning to appear was a function of this process.

More evidence is needed to test whether moving the goal box necessarily precedes the failure of latent learning to appear. Croake (1963) and a pilot study for the present work both produced evidence that rats can solve the problem with the goal box moved if modifications are made in the design. The present experiment manipulated the time the _S_s were permitted to explore, one group receiving the same amount of exploration provided by Seward and the other receiving three times that amount. Other procedures, described below, were used to reduce the conflict of stimuli arising from moving the goal box during feeding.

_Test Croake's Study_. Another facet of the problem for this experiment stems from a study by Croake (1963). His experiment was a useful model of the Type 5 latent-learning design, and it functioned in much the same way as the present work. In his T-maze, however, the goal boxes were exposed to view from the choice point. It seems unlikely that this design affected the validity of his experiment, because rats behave as if they are shortsighted, and Croake's criterion line was 16 inches from the goal box. Nevertheless, shortsightedness has not been adequately demonstrated. The present experiment attempted to replicate the essential design of Croake's work.

Hypothesis. Rats, when given an incentive, will run from the starting point of a T-maze toward a designated goal-box position. The probability of such successful runs is a function of the amount of time spent exploring the maze when no food, water, or obvious reinforcement is present. The null hypothesis is that the experimental groups of Ss are taken from a common population in which the probability of solving the problem is ½.

## Method

Subjects. Ss were male, naive, Long-Evans rats, 60-85 days old when the exploration schedule was started. Fifteen were raised in the Central Washington State College laboratory. One was discarded for emotional behavior--it failed to rest quietly in E's hand, and while being moved in a carrying box, it would run, changing direction rapidly without pausing.

An additional 20 Long-Evans rats 65 days old were purchased from a Seattle supplier. Two were rejected when they failed to consume food in the goal box during critical trials.

The remaining 32 _S_s were assigned randomly to two groups of 16 each. Group 1 explored the maze for an accumulated total of 1½ hours; Group 2 explored for 4½ hours.

_Apparatus_. A flat gray T-maze with stem and arms each measuring 4 X 32 inches was used. An alley 8 inches long projected at right angles from the end of each arm of the maze and led to two goal boxes. Thus the goal boxes were visible only from the ends of the cross arm. Pencil lines across the floor of each arm of the T-maze midway between the choice point and the corners leading to the goal boxes were criterion lines for correct or incorrect choices. _S_s typically ran from the starting position, hesitated and circled at the choice point, then moved toward a goal box, crossing the criterion line and seeming to accelerate as they approached the corner leading to the goal box. Only once did a S reverse himself just after crossing the line. (His original choice, an error, was counted.) The starting end of the stem was equipped with a guillotine-type gate through which _S_s were introduced into the maze at the critical trials.

The goal boxes were 8½ X 9 inches, and one of the four walls had a 3 inch hole ½ inch above the floor to permit the entrance of Ss. This entrance could be closed with a sliding gate inside the box. The boxes were not rigidly attached to the maze. The wall containing the entrance was simply butted against the open end of the 8-inch alley leading from the maze. This arrangement produced a tight joint between the boxes and the maze, and it permitted easy removal of the goal boxes during the critical tests.

The goal boxes were unlike. The sandpaper box, located on the left from the starting position, was white with coarse, black, floor-sanding paper glued to the floor, rough side up. The other box had rust colored carpet on the floor and three walls. The entrance wall was light gray. The carpeted box was lightly scented each day with Old Spice deodorant stick, and the sandpaper box was scented with Lander deodorant stick. The latter scent was sweeter and stronger. (Six judges attempting to match the sticks with the scents in the boxes were all successful.) Thus Ss had visual, tactile, olfactory, and kinesthetic (they climbed the carpeted walls) cues to distinguish the boxes.

The maze was placed on a table in an 8 X 8 foot room brightly illuminated with flush-mounted, overhead fluorescent lights. The stem of the maze was directed toward a door leading to an anteroom. The stem of the maze was directed toward the door to avoid exposing *S*s to any right-or-left cues during critical tests when *S*s were brought from the anteroom where they had been fed to the starting gate of the maze for the critical test. Subjects were detained or transported from their home cages in square, white plastic boxes 14 inches square and 6 inches deep with wire mesh floor and lid.

A Gralab timer was used to time exploration periods.

*Procedure*. Preparation for the critical trials consisted of handling *S*s, providing them with maze-like experience, and permitting them to explore the maze.

Anxious behavior in *S*s was reduced by handling them. *E* took each *S* from the home cage, held it till it stopped struggling, and put it in the plastic carrying box. After a group of *S*s were in the box, each was returned to the home cage in the same manner. *S*s were handled in this manner seven times over a period of four days.

A second procedure to reduce anxious behavior was to permit *S*s to explore the maze with the goal boxes detached. Groups of from 7-20 *S*s were provided with this limited exploration for three periods totaling 2 hours. Then small groups of 3-4 *S*s were given six 10-minute periods of experience over an interval of 4 days. *S*s were always introduced into the maze at one of four locations: (a) the starting point, (b) the choice point, (c) the junction of the right arm with its 8-inch alley, and (d) the left arm-alley junction. These locations of introduction were rotated. Ss were always removed from the maze from whatever random position they occupied at the end of a given period. After removal Ss were always detained 20 minutes in the carrying box before being returned to the home cage. Periods of maze-like experience were always separated by a 2-hour interval.

Exploration of the maze was the manipulated variable in this experiment. The distinctive goal boxes were placed in position on the maze, Ss were permitted to explore them as well as the rest of the maze. The location at which Ss were introduced into the maze, the place from which they were removed, the 20-minute confinement after exploration and before being returned to the home cage, and the minimum 2-hour interval between exploration periods were all controlled for exploration periods as they were (described above) for maze-like experience periods.

Group 1 was provided with 90 minutes of exploration composed of eight 10-minute and two 5-minute periods. Group 2 accumulated $4\frac{1}{2}$ hours of exploration with twenty-four 10-minute periods and six 5-minute periods. This amounted to three times as much exploration as Group 1 had.

All Ss explored in groups of 3-4 during the longer periods and individually during the shorter periods. Three or four exploration periods were provided each day except for one day in which there were five. Ss were randomly divided into the two groups after they had completed eight exploration periods.

A feeding schedule was initiated on the first day of exploration in which Ss were fed two hours and deprived 22 hours each day. Water was always available to Ss except for the day preceding the critical tests. Eight Ss in Group 1 had water available during this pre-test day. The feeding period was from 1:30-3:30 p. m. with a 30-minute tolerance to accommodate other scheduling. Three exploration periods preceded and one followed feeding on a typical day. Ss were fed Purina Rat Chow bricks.

About 30 minutes before the critical trials, each S was provided with a final 3-minute period of maze exploration. Then S was placed in a carrying box and isolated in a remote place for 25 minutes before the critical trial.

Each S was given a single critical trial designed to measure whether latent learning had occurred during exploration of the maze. At the time of this trial, Ss had been deprived of food and water 22 hours.

The essential procedure of the critical trial includes placing a food-deprived S into one (randomly assigned) of the two unlike goal boxes where, for the first time, it finds food. When S begins to eat, it is removed and placed in the starting box of the T-maze. If S runs back through the maze directly to that goal box in which it was just fed, a correct choice is scored. If not, an incorrect choice is scored. But, it will be recalled, Seward's second control experiment provides evidence that for successful runs rats depend on stimuli to which they were exposed after being fed. After feeding and while being carried from the goal box to the start box, Ss were being exposed to stimuli (visual, kinesthetic, or extra-maze) enabling them to return to where they had been fed. To control these post-feeding stimuli, Seward put the goal boxes in a different location to feed Ss. Then if Ss were exposed to stimuli after feeding, the stimuli would not aid Ss in making a correct choice at the choice point. But then Seward's animals could not solve the problem. Some, described elsewhere, concluded that rats cannot solve the problem if the goal boxes are moved. This reasoning gives rise to the procedure for the final critical trial.

The two unlike goal boxes were removed from the maze, gates within the boxes were closed, a brick of Purina Rat Chow was wired to the floor with each box, and the boxes were taken into an anteroom, out of sight of the maze.

If post-feeding stimuli enabled Ss to run back to the feeding box when the box was on the maze, post-feeding stimuli could cause Ss to attempt to run back to the anteroom after they had been fed in a goal box in the anteroom. Seward observed that after his goal boxes had been moved to just behind the start box, Ss, instead of running the maze, tried to climb back out of the starting box to the goal box.

For these reasons, during the critical trials of the present experiment, Ss were carried closely in an enclosed pouch formed by E's hands and stomach.

Each S was carried into the anteroom and placed in the goal box to which it had been randomly assigned. Once in the goal box S would typically examine the gate, now closed for the first time to prevent his exit from the box, start to eat the brick, explore the box, eat a few more seconds, return to the gate, and return to the brick. After about a minute of this activity, E took the S, holding it closely, carried it from the anteroom to the maze room, and introduced the S into the starting gate of the maze. Neither goal box was on the maze; both were in the anteroom. Once inside the starting gate, S would typically turn around, face the gate, and remain motionless for some ten seconds. Then S would move to the choice point, perhaps retreat to the starting point, then run again to the choice point, circle, and move with seemingly increasing speed toward one of the former goal-box positions. Choices were recorded as _S_s crossed a criterion line.

The Chi-square statistical measure of significance was applied to each group and to the combined groups.

## Results

Group 1 with 1½ hours of exploration produced nonsignificant results. Eight of the 16 _S_s chose the inappropriate route from the choice point. Group 2, however, with 4½ hours of exploration, produced significant results. Thirteen of the 16 _S_s made correct choices ($\chi^2 = 5.06$, df = 1, $p < .025$). Combined scores of the two groups produced nonsignificant results (see Table 1 below).

TABLE 1

Latent Learning: Function of Exploration Time

| Group | n | Errors | $\chi^2$ | df | _p_ |
|---|---|---|---|---|---|
| 1½ hours exploration | 16 | 8 | 0.0 | 1 | $> .95$ |
| 4½ hours exploration | 16 | 3 | 5.06 | 1 | $< .025$ |
| Combined groups | 32 | 11 | 2.53 | 1 | $> .10$ |

These results are interpreted as supporting the hypothesis. The difference between the results of Groups 1 and 2 are attributed to the manipulated variable. *S*s having had 1½ hours of exploration did not solve the problem, but *S*s with 4½ hours of exploration did solve it. The null hypothesis is rejected; the two groups are not from a common population having a probability of ½ of solving the problem.

Did *S*s tend to run to one goal box more often than they ran to the other? Table 2 indicates there was no significant preference for one box above the other.

TABLE 2

Goal-Box Preference

| Group | Goal-Box Assignment | n | Success | Failure | $\chi^2$ | df | *p* |
|---|---|---|---|---|---|---|---|
| 1 | Carpeted | 8 | 4 | 4 | 0 | 1 | $>.9$ |
| 1 | Sandpaper | 8 | 4 | 4 | | | |
| 2 | Carpeted | 8 | 7 | 1 | 0 | 1 | $>.9$ |
| 2 | Sandpaper | 8 | 6 | 2 | | | |
| Combined | Carpeted | 16 | 11 | 5 | 0 | 1 | $>.9$ |
| | Sandpaper | 16 | 10 | 6 | | | |

Of the eight errors in Group 1, four failed to go to the carpeted box, and four failed to go to the sandpaper box. Of the three errors in Group 2, two failed to go to the sandpaper box, and one failed to go to the carpeted box. If a preference for one box existed, it was not reflected in the tests. Table 2 records the nonsignificant $X^2$s for goal-box preference.

Half of Group 1 had water available to them during the 22 hours preceding critical trials. Their performance was slightly better (five successes in eight runs as compared with three successes in eight runs) than the water-deprived *S*s. Table 3 displays a nonsignificant $\chi^2$ between these *S*s.

TABLE 3

Water-Deprived Compared with Water-Available Performance

| Group | n | Success | Failure | $\chi^2$ | df | *p* |
|---|---|---|---|---|---|---|
| Water-Deprived | 8 | 3 | 5 | .25 | 1 | $>.30$ |
| Water-Available | 8 | 5 | 3 | | | |

These results support the view that rats can learn without obvious reinforcement. For the problem embodied in this experiment, the amount of time *S*s were permitted to explore the maze was a determinant of successful solution.

## Discussion

_Learning Without Reinforcement._ Because _S_s in the present experiment appear to have learned without obvious reinforcement, reinforcement theory does not adequately explain the behavior. In Type 1 latent-learning experiments _S_s were always removed at the goal point. Because this process may have reinforced running to the goal point, _S_s in the present study were not run through a maze, but were permitted to explore the maze freely, and they were removed from whatever position they occupied at the end of the exploration period. Also, Type 1 _S_s were taken to cage mates after removal, a process which may have been reinforcing. _S_s in this experiment were detained in a box 20 minutes before being returned to the home cage. Similarly, the food and water acting as primary reinforcers to satiated rats in Types 3 and 4 latent-learning experiments were removed in the present work.

A theory has reached the limits of its explanatory usefulness when it says, in effect, "A stimulus and response connection can be made only in the presence of a reinforcer, but with this type of behavior we cannot specify the reinforcer." Logan (1959, pp. 334, 335), discussing the elusive reinforcers in latent-learning studies, comments,

> The more common interpretation is that learning (rather than unlearning) occurs during the preliminary exposure, and the reinforcement theorist must, in this case, assume that some (admittedly still unspecified) source of reinforcement is available. The fact that performance typically improves without apparent reward is consistent with this assumption.

Hilgard (1956, p. 20) described the typical reinforcement theorist's response to the Blodgett type experiment, outlined earlier, with the following:

> Reinforcement theorists usually made much of the decrease in errors during non-rewarded trials in latent-learning experiments as evidence that <u>some</u> reinforcement was present before reward was introduced.

Thistlethwaite, not satisfied with unspecified reinforcers, commented,

> If the indispensibility of reinforcement for learning is to be granted, it must be possible to demonstrate for <u>each</u> instance of latent learning or of irrelevant-incentive learning (1) that some source of reinforcement was operative in the experimental setup and (2) that the changes in responses which are taken as evidence of the learning can be deduced on the basis of this alleged reinforcement.

MacCorquodale and Meehl (1954, pp. 212, 213) agreed with Thistlethwaite's position if the word "demonstrate" could be weakened to "render probable."

The concept of reinforcement is certainly unwieldly in explaining latent-learning behavior, and so long as the reinforcers are unspecified, it is not illuminating to say, "They must be there or the learning would not have occurred."

It should be noted that theorists are not completely at a loss to suggest factors which could be acting as reinforcers in this experiment. Exploration itself could be thought of as reducing drive stimuli. Sensory deprivation work suggests that within limits any visual, olfactory, auditory, kinesthetic, gustatory, or tactile stimulus is reinforcing. Perhaps an experiment could be designed to demonstrate that air is a primary reinforcer to a choking animal and a secondary reinforcer to a breathing animal. But a theory has generalized its concepts beyond testability when it says in effect, "A stimulus and response connection can be made only in the presence of a reinforcer, but reinforcers are virtually always present since the breathing of air and a major share of all sensory activity are reinforcing." Thus reinforcement theory becomes vacuous as it (1) necessarily invokes a reinforcer, even if unspecified, for all learning or (2) postulates that virtually all behavior is reinforcing.

Some relief from this dilemma may be promised by the quantification of the reinforcement concept. Postulating that mere visual or auditory activity is itself reinforcing is not absurd if they are demonstrated to be weaker than and eclipsed by the presence of such powerful reinforcers as food, water, and sexual activity. Then in the absence of the latter obvious reinforcers, learning could be explained on the basis of the weaker reinforcers, and in the presence of the powerful reinforcers, the weaker ones would not be significant. Anyone who believed in the fertility of quantifying reinforcement theory to this degree would probably be considered a reinforcement theorist.

Tolman, of course, did not believe reinforcement is always necessary for learning (1949, p. 154), so he did not need to account for learning without reinforcement. But he said, "There must be invoked a . . . curiosity . . . drive which gives positive valences to all parts of the maze" during latent learning (1959, p. 125). If cognitive theory proposes to explain learning by "final values" and/or drive stimuli, then cognitive theorists may face a task comparable to that of the reinforcement theorists. Of course, in the case of latent-learning experiments, cognitive theorists cheerfully name the source of the valence: curiosity drive. But this concept needs more than a name. What gives rise to it? How can it be defined? How can it be quantified?

The results of the present experiment seem to favor cognitive theory above reinforcement theory because the terms "expectancy," "map," "route," and "select" seem much more adapted to describing the latent-learning phenomena than do "stimulus," "evoke," "response," and "reinforcement." But to define the former terms rigorously, cognitive theorists tend to resort to the latter terms. Perhaps the present experiment is more useful as an indicator of the work ahead for the two schools of thought than it is as an indicator of the better theory.

Control Seward's 1949 Study. What difference in treatment explains the success of Seward's former group and the failure of his latter group in solving the problem? Three possibilities are evident: (a) *S*s in the latter group may have been 'misinformed'--they were exposed to stimuli at the critical test indicating that the goal box was no longer beyond the choice point of the T-maze, but was now immediately behind the starting point; (b) members of this group were delayed in the starting box while *E* was returning the goal box to its normal position on the maze; and (c) members in the successful group were exposed to visual and kinesthetic stimuli while being moved from feeding in the goal box to the starting box--these stimuli would indicate the normal, true position of the goal box. If this last difference affected the results, an investigator would have to conclude that, because these *S*s encountered after-feeding, extra-maze, directional stimuli, their success could be attributed to reinforced learning.

The results of the present experiment are not definitive in isolating the factors causing the difference between Seward's successful and unsuccessful groups. The present design effectively controls the extra-maze stimuli by moving the goal boxes, but not without introducing an extraneous variable--new stimuli which may cause Ss to attempt to run to the new position of the goal box. And this new variable was Seward's problem. Negative results by the present $1\frac{1}{2}$-hour group strengthens the view that it is premature for Seward or the reviews of latent-learning literature to list Seward's main study as a positive illustration of latent learning.

*'Misinforming' the Rats*. One of the most unequivocal conclusions stemming from the present work is that moving the goal box does not necessarily lead to failure of latent learning to appear. Kimble wrote that Seward's procedure of moving the goal box "leads to the failure of latent learning to appear" (1961, p. 230). Seward (1949, p. 181) and Thistlethwaite (1951, p. 105) both suggest the same viewpoint.

Two techniques were used to handle the 'misinforming' problem. The problem, briefly, is that the rats, without obvious reinforcement, may learn the location of the two goal boxes during exploration, but later the boxes are moved and the Ss are provided with powerful reinforcement. Obviously, any stimuli associated with the box in the new location and in the presence of reinforcement will be antagonistic to previous non-reinforced learning of the box's normal location.

One method of meeting the 'misinformation' problem in the present experiment was to provide three times the exploration time for one group prior to the 'misinforming.' Second, in an effort to intercept antagonistic stimuli, E enclosed each S in his hands, taking care to cover the eyes during transit related to the moved goal box situation. A lesser factor may have been control of the time lapse during transit from the feeding to the starting box. Seward's goal box was against the starting, and although he delayed starting most of his Ss, he may have popped his Ss from the feeding box to the starting box in a fraction of a second--much less than the time interval normally required by the Ss to travel from a goal box to the start box. This time interval may have produced conflicting stimuli. The time intervals in the present experiment were probably better matched.

Test Croake's Study. In Croake's (1963) maze the goal boxes were visible from the choice point. For reasons cited earlier it is doubtful that rats respond to visual stimuli at the distances involved. Positive results by the present 1½ hour group would have supported this view, but this group showed no evidence of learning. Although this seems to underscore the question of his exposed goal boxes, the success of his 1½-hour Ss may have been the result of a simpler problem. His maze had no corners aside from the junction at the choice point. The present maze had two more corners and two additional 8-inch alleys. Also, Croake's Ss may have had a simpler problem regarding the moved goal boxes. He moved them, but he kept them in the same room. Another difference was that Croake's Ss were 200 days old in contrast to 80 days of age for the present Ss. Finally, Croake's preliminary handling of Ss to reduce anxious behavior was more elaborate, consuming over 60 days. Present Ss were handled for only about 4 days.

Criticism of the Present Design. During the progress of the present experiment certain weaknesses in its design became apparent. Perhaps the most vital are those which may have contributed to the failure of the 1½-hour group to solve the problem. The 2-hour-a-day feeding schedule was started on the first day of the experiment, and this schedule had been in effect only 3 days when Group 1 was given critical trials. This may not have been enough deprivation to insure appropriate performance. One study of feeding rats 2 hours a day at 24-hour intervals indicates an adjustment period of from a week to 10 days before food consumption stabilizes (Lawrence and Mason, 1955). The feeding schedule should have been instituted a week before training trials. Other suggestions for maintaining effective food deprivation include keeping Ss from fecal and bedding material and using carrying boxes made of material other than gnawable plastic.

Another factor that may have detracted from the ability of the 1½-hour group to solve the problem was the limited time in which individual Ss could reduce anxious behavior exhibited in the white carrying boxes. Usually Ss were in these boxes in groups of four. Members of the 1½-hour group were in these boxes alone while being carried to an exploration period and for the 20-minute detention after exploration for only three periods, one being the occasion immediately preceding critical trials. These Ss seemed to crouch in a corner and startle more readily when alone in the white box than in other situations.

The present design would be improved by more control of factors correlating with activity level of the Ss during exploration. When exploring was scheduled shortly after the 2-hour feeding period, they seemed to spend more time sleeping than usual. Similarly, if the air was too warm, or if Ss were on their fourth or fifth exploration period of the day, there seemed to be less than the normal amount of exploration activity. Limiting exploration periods to two a day may stabilize the quantity of activity.

At the beginning of the experiment it seemed that Ss spend a disproportionate amount of time in the carpeted box. Although this tendency seemed less apparent later, exploration may be more effective if Ss spent approximately the same amount of time in each of the goal boxes.

Criterion lines in the present study were located midway between the choice point and the corner. One rat crossed this line heading the wrong way. Before reaching the corner, he stopped and returned. This was counted as an error. Because of the oscillating behavior typically displayed at the choice point, it appears that the nearer the criterion line is to the choice point, the more random behavior is likely to be recorded. If the investigator is not interested in how often Ss reverse their directions, nor how far they travel before reversing--so long as they did not come within view of the goal box before reversing, then the criterion lines should be placed as near as possible to the corners leading to the goal boxes.

Another source of randomness in the results may be emotional Ss. These are rats which continue to struggle in E's hands, and they quickly change directions of running without pausing. One of the early Ss demonstrated this behavior, was given a critical test, ran up the stem and turned (the wrong way) at the choice point without pausing. In typical runs Ss paused at the choice point.

Future work in latent-learning designs may include experiments in which Ss are provided with exploration without performance. Gleitman (1955) and McNamara, Long, and Wike

(1956) have worked on learning without performance. Another step in reducing the factor of reinforcement in latent-learning experiments is to provide exploration while Ss are operationally satiated.

## Summary

This has been a latent-learning study exploring variables from Seward's 1949 experiments. These variables include (a) extra-maze cues to which Ss may be exposed after feeding and before the critical trials, (b) the length of time Ss are permitted to explore a maze, and (c) new and potentially antagonistic cues indicating the position of a moved goal box. The present study indicates that if extra-maze cues are controlled, Ss can solve a Type 5 latent-learning problem like that of Seward's 1949 experiments, that latent-learning is a function of exploration time, and that antagonistic cues indicating the position of the moved goal box can be controlled permitting Ss to solve the latent-learning problem.

Theoretical questions underlying all latent-learning experiments are (a) whether reinforcement is necessary for learning and (b) whether latent-learning behavior is better explained by cognitive or by reinforcement theory. The present study indicates that reinforcement theorists may maintain the growth and usefulness of reinforcement theory by identifying and quantifying reinforcement. Although this study tended to favor cognitive theory, those theorists may expand their theory's usefulness by identifying and quantifying the determinants of valence.

Sixteen rats, Group 1, explored a T-maze for 1½ hours; Group 2 explored 4½ hours. The T-maze had unlike goal boxes and contained no reinforcement. Goal boxes were removed to an adjoining room. Each rat was fed in one and returned to the maze to run. Group 1 produced nonsignificant and Group 2 produced significant results ($\chi^2 = 5.06$; $df = 1$; $p < .025$). Latent-learning performance was deemed a function of exploration.

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