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AN EXPERIMENTAL ANALYSIS OF LEARNING IN THE OPOSSUM*

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Summary

Within the last few years an interest has developed in the learning and discriminative behavior of the opossum. It was assumed that an animal with such a primitive brain would not be very successful in the learning procedures used with the rat and other animals. The present summary indicates the opossum has been studied in many different situations used on other animals. The list includes conditioning, different types of maze learning, color and object discrimination, operant conditioning, and other behaviors. The surprising result is that the opossum is highly successful in all types of learning situations. It was not expected to be as successful in discrimination as animals with a larger brain, but it was on a par as far as learning was concerned. The only type of problem it failed completely was the double alternation one, which few animals can solve.

A. Introduction

One of the most intriguing things observed by the early settlers to the American continent was this strange and new animal they found in the woods. It was unlike any animal observed on the European continent, and, of course, it had no English name. An early description given is that of the Frenchman Du. Pratz, an early 18th century settler.

> The rat-de-bois' head and tail is like a rat's. He is as big and long as an ordinary cat. His legs are shorter, his paws are longer and his toes are armed with claws; his tail almost without hair and made to hook, because when taken by this member, he winds himself at once around the finger. His hair is gray and although fine is never smooth. The Indian women spin this and make garters of which they dye red. They hunt fowl at night and suck their blood but never eat them. Ordinarily no other animal is seen to walk so slowly, and I overtook one

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> often walking at my usual pace. When he sees that he is about to be caught, his instinct leads him to pretend death. and is so well carried out that if you were to kill him and cook him, he would not move or show any signs of life. It is only when at a great distance, or well hidden, that he starts off to quickly hide in some corner or among bushwood.
>
> I have often been surprised at the great number of this animal seen everywhere, when everything seems to conspire to their destruction, for this animal is of extraordinary slowness, defenseless, and even though able to climb well, his little ones are born on the ground. It is believed that no other animal fights him (20, p. 13).

Various names were applied to this animal in these early days, including bush rat, rat of the woods, the stinker (since those reared in the wild usually have a foul odor), and little pig. Captain John Smith gets credit for first calling the animal opossum. It was after Linnaeus that the name Delphinis Virginia—from the Greek Di-two, Delphys-uteri—was used. For some reason, Linnaeus substituted an i for the y, and that is the way it remained. It is possibly because of the animal's slow pace of movement, its tendency to "feign death" in the wild, and its apparent unresponsiveness that it was considered the "dumb one" by all early observers. If the animal is as unintelligent as it has been considered, it is surprising that it has survived so long. Its parents were roaming our continent with the extinct dinosaurs around 70,000,000 years ago.

The opossum belongs to the second order of mammals, the Marsupialia. The female has a marsupium (ventral pouch) or marsupial folds surrounding the nipples; the uterus and vagina are doubled and there is no placenta for developing the eggs, which begin development in the uterus. The eggs are extremely small, about 1.75 mm in diameter. Hartman's studies indicate a gestation period of 12 days and 18 hours. At this time the animal is in a low stage of development (20 of them will fit into a teaspoon) and it must find its way from the cloaca to the pouch and locate the teats within the pouch. The earliest observers of the opossum could not understand how this could occur in an animal of such a low stage of development. Some thought the mother placed them there with her teeth. Others thought the animal had a negative response to gravity, and pulled upward into the pouch, since the mother sits upright with her hind legs extended during birth of the animal. Langworthy (37) found that there was no mechanism to respond to gravity at this early age, however, and none of the careful researchers found any evidence the animal was aided by the mother in this migration.

Hartman (20, p. 100) found the answer in his careful observations of the newborn opossums. The hind legs are inactive at birth, but the front legs are active and can be used to pull upward on the hairs of the mother as she sits upright. The animal then clings to the mother's hair, and since the rear legs are inactive, they can do nothing but hang downward. The front legs are used then to pull upward the full three inches to the pouch, where they enter and move the head from side to side until one of the 13 nipples is located. They then take the nipple into the mouth and begin the sucking process; remaining there as if fixed until around 64 days of age. At this time they have control of both pairs of legs, so they can leave the nipples and return. They begin to stick their heads out of the pouch and occasionally go outside and move about the area. It is at this time that they may be removed and fed milk by a small doll bottle. They can also begin to eat meat, and regular canned foods used for the human child. When reared in this manner, they become tame and easy to handle, never showing the "feigning" behavior so characteristic of the wild animals. They can also be used in all types of experimental studies on behavior.

It was while doing research at the Cornell Behavior Farm of the Cornell Medical College, under the direction of Dr. Charles R. Stockard, that we became interested in the behavior of the opossum. On one occasion, an opossum was brought in by one of the kennel boys, and we began to talk about the animal. Of special interest to him was the "playing dead" behavior observed by opossums in the wild when they are suddenly disturbed. The animal falls over on its side, curls up, and becomes completely immobile. No one seems to be able to fully explain the behavior. It probably is due to some type of physiological disturbance of the nervous system which acts as a protective behavior. Another question that was asked concerned the intelligence of the animal. The opossum was considered a "dumb animal, unable to learn very much, if anything" by the early observers as well as the opossum hunters of the South. However, very little was known of a scientific nature about the learning ability of the opossum. It was decided to build outside cages for opossums and plan a program of research on their learning ability. Since at this time we were carrying on conditioning experiments on the foreleg of the dog with the use of a conditioned signal plus shock, it was decided to determine if the opossum could develop an avoiding response of the foreleg to a conditioned signal and shock.

B. Learning Ability of the Opossum

1. *Conditioned Avoiding Leg Action*

For these experiments, the animal was confined in an apparatus as shown in Figure 1. There was a yoke around the neck to keep it forward, and a cloth harness under the rear legs to keep it from sitting down, as it tended to

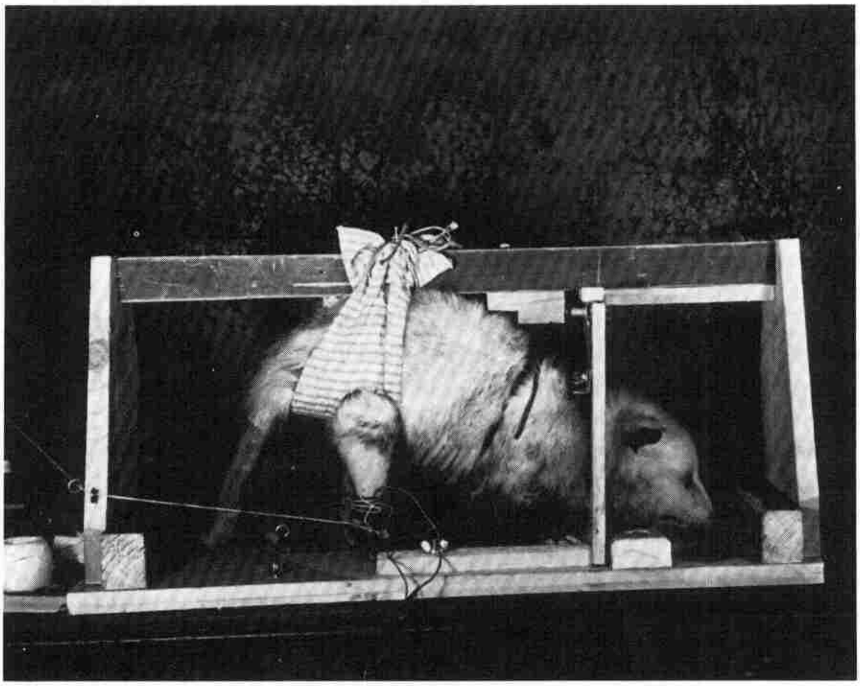

FIGURE 1
OPOSSUM IN THE CONDITIONING APPARATUS

do if not restrained. A shock just intense enough to cause a flexion of the leg was used as the unconditioned stimulus, while a door buzzer was used as a conditioning stimulus. Two studies of this type were completed; the first on a wild animal, and the second on one reared in the laboratory from birth, and thus more amenable to the handling involved (27). In both of these cases, after 300 signals in the first animal and 550 signals in the second animal, a specific foreleg action to the buzzer did not occur. That did not mean, however, that we did not have conditioning. In each case there was a conditioned breathing response, and in both cases there was action of the leg plus a total walking response, a total bodily reaction. This did not mean the animal could not learn; it only meant that its nervous system could not confine action to the one leg segment. This animal is so constructed that it tends to act in total bodily systems rather than in one segment when under a painful stimulus.

In order to determine whether the opossum had more success by reacting with total bodily systems rather than with specific leg action, other tests were conducted in which the animal was required to walk from one compartment to another of a two-compartment box in order to avoid a shock on the feet. The wild animal curled over on its side and became inactive, in which position it was insulated from the shock. In this case, the feint was protective. Three tame animals were used and all gave a conditioned walking response; animal 1 after seven signals, animal 2 after three signals, and animal 3 after five signals. All the movements were slow with long delays. The delay of animal 1 was 4.08 sec; animal 2, a delay of 4.98 sec; and animal 3, a delay of 2.72 sec. The opossum was a rather slow inhibited animal—there was no doubt about that—but that did not mean that it could not learn.

Since the opossum is rather slow and inhibited, it was of interest to observe the development of extinction. After the application of 63 positive signals in the experiment with animal number 2, the shock was eliminated. This animal failed to respond to the first signal without shock, and extinction appeared immediately. The animal did not respond at all for 10 signals of from 10 to 20 sec duration, with the escape door opened all the time. In the case of animal 3, the signal was given for a short time—below the delay level of response—without shock, and the response disappeared. After six signals of short duration, the animal did not respond at all to following signals of long duration. Animal 4 gave eight responses to the first 20 signals without shock—signals of short duration—and then no responses to the next 10 signals.

The ability to form extinction readily to a signal that no longer means danger emphasizes the inhibitive nature of the opossum. All these tests indicate that the animal can learn an avoidance response, but it also learns readily when the signal loses its significance for danger. Such behavior emphasizes the highly adjustable nature of the animal.

2. *Behavior in the Guthrie-Horton Puzzle Box*

It was evident from the above experiments that the opossum could form conditioned responses, even if it did not perform with a specific signal segment as did the dog. In a course on Learning Theory with graduate students at the University of Georgia, the work of Guthrie and Horton was discussed. Guthrie used cats in his study and maintained that "a combination of stimuli which has accompanied a movement will, on its occurrence, tend to be followed by that movement" (17, p. 23). Guthrie used a large experimental box made of glass in which the animal could be observed from all sides. The cat was placed in the back of the apparatus and had to open a door on the other side to get to food. In the middle of the box a pole was located which would open the door if moved slightly in any direction, then the animal could escape to food. Guthrie was interested in the movements involved and the change in patterns of movements as the animal was placed repeatedly in the apparatus. On the first three trials, the front door leading to food was left open; after that, the door was closed until the pole was touched. Guthrie gives many pictures of the cat showing that following a few random movements, the cat sooner or later would hit the pole in some fashion, either lean against it, nose it, or touch it with the foot, and the door would open and lead to the food. In the course of behavior, the movement became associated with the open door and food and became more specific and stereotypical. Sometimes it might have happened on one trial, sometimes on a number of trials, but all cats learned a specific movement which was repeated each time. According to Guthrie, this was what should have happened.

The class constructed an apparatus similar to that of Guthrie and proceeded to train an opossum (26). Our box had three sides of glass and was trapezoid in shape. The back side was made of ¼-inch plywood. A glass swinging door was located in the middle of the front side which would open when a pole erected in the center of the box was moved as much as ¼ inch in any direction. Since the animal used was wild, it would not perform during the daytime so the tests had to be made at night as the animal would take food only during this time. The behavior then had to be observed photographically, via flash gun and camera focused on the box area taking the picture as the pole was operated. Thirty-four pictures were taken of the animals' behavior; only the first three of these showed what may be called random behavior in an area behind the pole and not oriented toward the door. The remainder of the pictures showed the animal orienting toward the door and either pushing the pole with the back part of the body or using the head against the pole. All the early pictures showed clock time of late at night; as the behaviors progressed they came earlier during the period.

On the basis of analysis of the pictures, there seemed to be no doubt that the opossum learned within a relatively short time to operate the Guthrie puzzle box. The class was surprised that the animal settled down to such a specific behavior in so small a number of trials, and their idea about the ability of the opossum began to change. The animal became so proficient and active that it was used in a television demonstration of animal learning.

3. *Maze Learning*

A few years ago, Fink made an extensive comparative study of nine species of animals in a special maze, including man, pig, dog, goat, chick, rat, rabbit, cat, and various species of turtle (11). The apparatus required no other action than that used to get food in its natural environment. No manipulation of any object was necessary to learn the maze, so different animals could be employed. In the case of man, a hand maze was used as a "miniature" of the animal maze and the blindfolded *S*s pushed the index finger of the right hand to the goal. The *S*s were blindfolded, since it was obvious that the human could learn the maze readily by the use of vision. An experiment was planned at the University of Georgia to compare the behavior of the opossum with those animals studied by Fink (28).

The apparatus consisted of a rather large rectangular box with four parallel alleys leading off one side, and a choice area in front of the alleys. The alleys used on the opossums had a choice area 18 inches wide, four feet long, and two feet high. The two outside alleys were 28 inches long, while the two inside alleys were 14 inches long. At the end of each alley there was a 90 degree turn toward a partition running through the center of the box. This gave a place where food could be hidden and not observed until the animal completed the run to the end of each alley. The maze was covered by wire and hinged top so that each animal could be removed after it completed a run. A two-foot square box was located in the center outside the choice area with a sliding door which released the animal for each test. The problem for each animal was to locate food at the end of the alley being used. Only one run was made each day, at the animals' regular feeding time. The alleys were numbered 1 to 4 beginning on the left alley.

Five opossums were tested. At first, food was placed in alley 3. In order that the alley should not be located by odor of the meat used as a lure, some meat was placed on the top of both back corners of the maze. The animal was required to find the path to food and was tested until it learned the particular path, and then made 10 straight runs without error before it was considered to have learned the criteria. The food was then shifted to alley 2, then to 4, and then to 1, and the same procedure followed in each.

Fink had used five different types of scores in his study but, for the present report, only what he called the P score is necessary to indicate the relationship between his animals and the five opossums. P is the sum of trials required for learning the four alleys. Table 1 shows the average scores of the

TABLE 1
COMPARATIVE RESULTS OF FINK ARROW MAZE

Animal	P score
Man	14.8
Opossum 2	24
Opossum 1	27
Opossum 5	27
Opossum 3	29
Opossum 4	38
Pig	31.8
Dog	38.4
Goat	54
Chick	46.4
Rat	53.7
Cat	61.1
Rabbit	67
Turtles	Below this level

animals used by Fink and those made by the opossum. It can be observed that all the opossums except one came between Man and the other animals, and even this one had a rather high score. The time required for each run decreased gradually from the first to the fourth alley.

It is possible that the proficiency of the opossum in the Fink maze was due to the fact that the animal did not seem to be disturbed by the various stimuli in the environment. Fink states that many of his animals jumped around a great deal, and responded to every sound or movement in the maze situation. Many of his animals repeatedly went to the same alley in which they found food the previous time. The opossum eliminated the nonreinforced alley at once, and then went to another. This behavior occurred much faster after the first alley was learned and then not reinforced. This ability to unlearn a behavior was also found in the above study in which the animal was required to run from one compartment to another when a bell plus shock on the feet was used.

4. *Maze Learning in Young Opossums*

The students in the Learning Theory class were so intrigued with the behavior of the opossum in the Fink Arrow Maze they decided to do a preliminary study of the young animals in a T Maze. The animals used in this study were reared in the laboratory as soon as they could leave the pouch and were more amenable to handling than the wild animals.

For the preliminary study the students constructed a T maze. The maze consisted of a series of T's with one arm of each T eventuating in a cul-de-sac or blind alley. The present maze consisted of five T's with a start alley in the side of the first T and a covered end of alley 5, where the reward was placed. Each T was 18 inches long, four inches wide, and was covered with wire so the animal could not escape. There were two blind alleys on the end of each T. Each turn where the T's joined either led to the blind alleys or down the open side to the next T. During the test a piece of horse meat was placed in the goal. In order to run the maze correctly, choices of left-right-left were required. Since the animals were only 70 days of age they were quite inactive at this stage. A buzzer was sounded at intervals during the early stages of training because this tended to encourage movement.

The criteria for learning was to run 10 trials without errors. The results were as follows: Animal 1, 14 trials with 13 errors; animal 2, four trials with one error; animal 3, four trials with two errors; and animal 4, four trials with four errors. An error was counted when the animal made a wrong turn at a choice point. There was a gradual decrease in time of the run from the beginning to the end of the tests in the case of each animal.

Following the above preliminary observations of the behavior of the young opossum in the T maze, James and Turner (33) planned an experiment in which the young animals were compared with the grown rat in the Lashley II design maze (38). This maze had been used extensively and a great deal was known about the rats' proficiency in it. The maze used was 38 inches by 18 inches by six inches, with a center 4½-inch runway and three cul-de-sacs and a food compartment on the sides. An incorrect response was contingent on the animal entirely entering into an incorrect alley. Five consecutive errorless trials constituted the learning criterion. The animals were tested five times daily. Seven young opossums approximately 60 days of age were compared with seven rats 90 days of age in the tests.

The results of the study are indicated by the Vincent curve in Figure 2. The difference in the overall mean errors for opossums (16.9) and rats (30.9) was statistically significant ($t = 2.46$, $df = 13$, $.05\ p > .02$). A possible explanation for the relative superiority of the young opossums was that these animals are less distractible and less curious in the exploratory behavior than the white rats, and it was possible that this difference was responsible for faster learning in the present tests.

5. *Test for the Ability to Use Vision and Simple Discrimination*

It had been assumed by the early hunters that the visual ability of the opossum was rather poor. In the first studies with the wild animals in the laboratory, it was true that they seemed to respond to an approaching

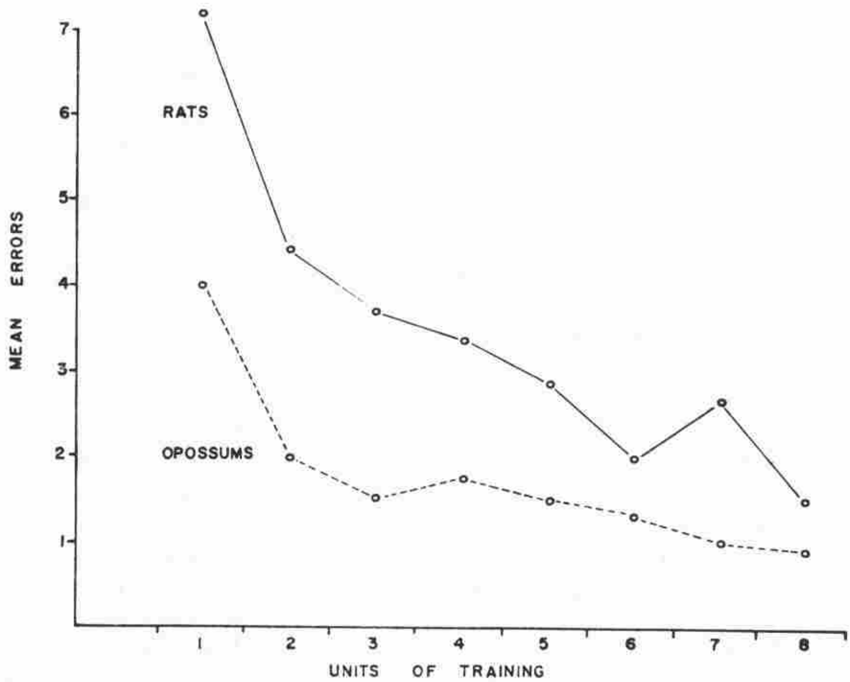

FIGURE 2
DIFFERENCE IN LEARNING OF THE OPOSSUM AND THE RATS IN THE LASHLEY II MAZE
One unit equals ⅛ of the trials.
From James, W. J., & Turner, W. W., III. Experimental Study of Maze Learning in Young Opossums. *Psychol. Rep.*, 1963, **13,** 921-922, Figure 1.

object, such as a stick, only when it was very near the head. This does not mean, however, that the animal did not see the object before it was near. The animal as a rule is very inactive in any case, and it may not respond until the danger is obvious.

Hence, an experiment was conducted which required the animal to learn to open one of two doors to get to food, each door containing either a positive or negative signal for food (29). The apparatus was composed of a start box, a choice area, and two adjacent doors leading to compartments in which food was found. The choice doors were one-way and could be opened only by a push with the head. The choice area was two feet wide at the start box and broadened to a four-foot width at the entrance of the choice boxes. The distance from the start box to the choice area was four feet. One side of the choice area had glass so that photos could be made. The other sides were plywood two feet high, with a screen cover that could be lifted to remove the animals. Three pairs of stimuli were used: (*a*) a white-black vertically striped card (positive) *vs* a white card (negative); (*b*) a white-black horizontally striped card (positive) *vs* a black card (negative); (*c*) a black card with a small triangle in the center (positive) *vs* a white card with a small black triangle in the center (negative). Each triangle was equilateral with 1¼-inch sides.

A wild mature opossum that had been in the laboratory for a long time and was amenable to being handled was used in the experiment. For the first three trials, the two doors were left open so the animal could learn that food was in each side of the feeding area. After this, one door was locked with the negative signal on it, while the other that could be pushed open had the positive signal. At first, only one trial was run each day; later in the tests, as many as five were run in succession. Food was always placed in each compartment so that odor could not be used to select the correct door. The position of the positive card was randomly selected.

The results of this study left no doubt as to the animal's ability to separate the two signals. In test 1, the animal made five consecutive correct choices ($p = .03$) in the fourth block of 10 trials, and six consecutive choices in the 6th block ($p = .01$), and for the last three blocks of 10, it was above this level. In test 2, the proper criterion was reached in the second 10, and in test 3, in the third 10 trials. In any case, the problem did not seem to be difficult for the animal.

A somewhat similar study was reported by Glickman *et al.* (16), who compared the behavior of the opossum, sloth, and lemur in similar discrimination tests. In the case of the opossum, Glickman used a Y maze with three-foot arms. Each arm was one-foot wide with walls one-foot high. Each arm had a swinging wooden door where the arms came together and could be pushed open. The animal had to learn to select the door containing a white card to get to the food at the end of the alley. Ten trials were given each day with a criterion for learning 10 consecutive correct runs. Two animals were used from the Lincoln Park Children's Zoo, and they were rather tame. The two animals learned the test in from 120 to 130 trials. There was little doubt the opossum could learn this simple type of discrimination.

Comparable tests were made with the sloth and lemur in an apparatus modified to fit each animal. They were also quite successful in solving the problem.

6. *Reversal Learning in the Opossum*

In order to analyze a more complex type of behavior in the opossum, Friedman and Marshall (13) did an experiment on position reversal to determine if the animal could form a learning set. They used the same apparatus and procedure that had been previously used by Dufort, Guttman, and Kimble (9) with the rat. In this way, the opossum could be compared with the rat in reversal learning and ability to form learning set. A total of five opossums were used in the test.

The apparatus consisted of a start box, choice compartment, and two food boxes located 60 cm from the entrance to the choice area. The food boxes were separated by a 15 cm panel. In order to get food, the animal had to approach the correct box and nose the lid over it. The box was then opened and food was available. The doors were distinctly marked: the right door had a white card with vertical black stripes, while the left door had a white card with horizontal black stripes. A sliding door was arranged so it could close off both food boxes. Thus if a wrong choice were made, the animal could not go to the other box. After a few days of pretraining, in order for the animal to learn that food was in the boxes, and to determine the animals' preference for the right or left box, a series of right-left discriminations were run on each animal. The first series started with food in the one opposite to that chosen repeatedly in the preliminary test. In each series of runs the animal had to choose the correct box 11 out of 12 times, with the last nine in succession. At this time, the box which had been correct was now made wrong and the animal had to learn to shift to the food box that was formerly incorrect.

In the first series of 15 reversals, in which the animals were run four times per day, there was no consistent improvement in learning. In the second series, in which as many trials were run as necessary to reach criterion, there was great improvement, indicating formation of a position learning set. In another series of 15, in which there was a return to four trials per day, three of the animals continued to perform with few errors, indicating transfer of learning set. The opossum seemed to do more poorly than the rat, which is in agreement with the phyletic level of the two species. In any case, it was much better than would have been expected according to the usual tales of the behavior of the animal.

Another study dealing with the problem of reversals with the opossum was an attempt to place this animal in relation to those classified by Bitterman on the basis of experiments on probability and reversal learning (2).

Bitterman concluded that for tasks of habit reversal and probability learning, animals can be classified as either "ratlike" or "fishlike." A rat shows nonrandom probability matching and progressive improvement in habit reversal. The fish shows random probability matching and no improvement in habit reversal. According to Bitterman, monkeys, rats, pigeons, and turtles behave as rats, while fish, cockroaches, and earthworms behave as fish. Bitterman is interested in trying to find a method of comparing animals rather than the usual types of learning experiments.

The same type of experiment was done with five young opossums by Doolittle and Weimer (8) in which the animals were compared with rats. A T maze was used, and for 30 days each animal was given 20 massed trials per day, with the preferred arm of the T being randomly reinforced on 30% of the trials and the nonpreferred arm reinforced on 70% of the trials.

The opossums maximized the percentage of their responses to the 70% alternative, choosing it on 90 percent of the trials. The curves of performance of rats and opossum were exactly similar. Thus, Doolittle and Weimer conclude that the opossum can be classified with the rat in Bitterman's rat-fish dichotomy for spatial probability learning.

7. *Object Discrimination*

The above tests gave a great deal of information about the learning ability of the opossum as well as its discrimination. In a further test by James and McFarland (32), an attempt was made to learn something about object discrimination, as well as black-white discrimination of closely related signals. Three animals were used which had been reared in the laboratory since leaving the pouch so they were tame and easily handled.

The animals lived in large cages 2 × 2 × 4 feet high, with a large sliding door on one side. The animal could be released onto a platform when the door was raised in order to go to an operant apparatus used to deliver food. The operant box was on rollers so it could be placed near the animal in the early training, but removed later as far as 18 inches distant. The animal could walk out to the operant box and get food by nosing, or pushing with the feet, one of two levers, one on the right and one left, with a food pan between the levers. The discrimination objects were mounted vertically on pieces of plywood ¼ × ⅓ × 2 inches that could be placed in slots on each lever in a few seconds. The background of the objects was gray, and a 60-watt light was mounted above the area. During training, the objects were shifted according to the Gellermann Series (15) to a criterion of six out of 10 with at least three in series. Most of the tests were above this.

Discrimination between a circle (3¼-inch diameter) and a cross (3¼ inches each way, with tips one-inch wide) was made with great difficulty, requiring seven blocks of 10, but responses were correct after this. The animal failed to discriminate between a white square (3¼ inches × 3¼ inches) and a rectangular white piece (¼ inch × 1½ inches). It also failed to discriminate between a medium black disk (3¼ inches in diameter) and a small black disk (1⅝ inches in diameter). It did separate a large black disk (4⅝ inches in diameter) from the small disk (1⅝ inches in diameter). There was discrimination between the large black disk and a medium black disk (3¼ inches in diameter). The animal could also discriminate between the cube (3 × 3 inches) and the ball of the same diameter. These tests again indicated the opossum had much better vision than had been expected.

8. *Color Vision in the Opossum*

Since the opossum belongs to the second order of mammals, the Marsupialia, and since these lower mammals are not supposed to have good vision and since they live mainly a nocturnal life, it was thought that they did not have appreciation of color. In order to learn something of the nature of color vision in the opossum, Friedman (12) did a discrimination test on two opossums to determine just how successful they would be in responding to color. The same apparatus was used as described above in his reversal-learning test. There was a start box, a choice area, at the end of which were two stimulus panels. Each panel contained a circle of translucent plastic (3.8 cm in diameter) on which the colors were projected from the reverse side. If the correct panel were nosed, food was delivered. Standard Kodak Wratten Filters were employed in determining the color. One panel was positive with one color on it, and the other was another color which was negative. Proper criteria were employed in determining the discrimination, and brightness was controlled so this could not serve as cue for the behavior.

On the basis of the test, Friedman concluded that the opossum could separate red from blue, red from yellow, red from green, yellow from blue, yellow from green, and green from blue. The animal could also separate these colors from a neutral gray of the same brightness. During the test, a cat was also trained, but was not as successful as the opossum. Smyth (47) maintains in his work on animal vision, that the cat is color blind, as well as all mammals except man, ape, and higher monkeys. If this is the case, it is difficult to explain the results with the opossum. Friedman suggests that the "earliest placental mammals, which very closely resembled the opossum and were probably nocturnal, could similarly have retained color vision derived from reptilian ancestors" (12, p. 4). He further suggests that color vision in primates may be a primitive mammalian characteristic. This problem requires further study.

9. *Operant Learning in the Opossum*

In a preliminary study at the University of Georgia Laboratory in 1957, two wild opossums that had been handled for some time were placed in a large operant box used for dogs. One end of the box had a food trough with a lever suspended below it which would deliver a piece of meat when pushed. In the beginning, the animals were just placed in the box and food was delivered so the animal could become accustomed to the apparatus and sound, as well as to eating the food. Both animals would take food on the first day. One animal did not push the lever until the 10th day, while the second pushed the lever first on the 14th day of training. After this, they would both push for food without difficulty. Each animal would use either the right or left foot. It seemed to depend on what side was nearer the lever when first approached. In one animal, after the response was well established, an attempt was made to extinguish the behavior. This required 124 responses, with attempts toward the end of this number to attack the food pan and lever by chewing and biting both. After a few attacks of the apparatus the animal walked away from the area. Both animals died after a few months of training so no further information was gathered on operant behavior in them.

A more complicated and systematic study on operant behavior was done by Cone and Cone (4). They used a smaller operant box (24 cm × 36 cm × 30 cm) with a lever delivering .1 ml of water as reinforcement. Four tame animals were used which had been reared in the laboratory. All animals learned to respond within a short time, and all were trained on an FR-10 performance. When all had reached this level, one male and one female were shifted to FI one min, with the other two trained on other ratio schedules. One animal could respond on FR of 35 and 50. The female was also trained on FI of one min, and shifted later to FI of 1.5 min with high degree of response. On the basis of the behavior, Cone and Cone conclude the opossum can be used in many types of operant behavior on various schedules of reinforcement.

10. *Response to Stimulus Change*

Due to the general behavior of the opossum, one would not expect it to be very observant of minor stimulus changes in the environment. It has been shown that rats vary their behavior to minute variations of stimuli. Dember (7) provided evidence for this position by demonstrating that rats, when exposed to, but not allowed to enter, the arms of a T maze that had one black and one white arm, would, on the next trial, enter the arm that had been changed. Dember maintained that this spontaneous alternation could be explained in terms of "exploration of novel stimuli." Seventeen of the 20 rats tested by Dember turned to the alley which had been changed. Another similar experiment by Hughes (23) demonstrated the same behavior in ferrets (*Mustela utories*).

Platt and James (42) repeated the same experiment with eight opossums, 330 days of age, and found the same results with these animals.

Another study which corroborated the above results on the opossum was done by Tilley, Doolittle, and Mason (48). Two male and three female opossums were given massed trials in a T maze, and were found to alternate significantly, following the same general pattern as the rat.

11. *Phases of Activity in the Opossum*

All opossum hunters know the time to catch the opossum is during the night, since they are rarely observed in the wild during the day. Cone and Cone (6) were interested in the effect of light on the phases of activity in the animal. They measured the activity in a specially prepared cage under darkness and five degrees of light ranging from weak to intense. The opossum was significantly more active under three levels of low illumination than under three intense illuminations tests. They were also more active at night than in daylight. The addition of high intense levels of illumination during the opossum's low daytime phase of action led to increased cage activity, while the addition of these same illumination levels during high nighttime activity led to decreased activity. These differences emphasize the relationship between the effect of light and the animal's normal circadian rhythm cycle.

In another study on activity, Cone (5) studied the activity of opossums under periods of 24-hour darkness contrasted with periods of light 12 hours and dark 12 hours. Under LD 12:12, the period of greatest activity was midnight, while under dark 24 hours, the peak occurred an hour later. The period of inactivity under LD 12:12 lasted for the entire light period, while it lasted from nine to 10 hours under total darkness for 24 hours.

Another study on general activity corroborates that of Cone. Bombardieri and Johnson (3) sampled sleep and action patterns, as well as other behaviors, in six opossums for 24-hour periods. In general, the animals were awake and grooming between 6 PM and 8 AM, with most other types of activity occurring between 10 PM and 8 AM. The *S*s spent the rest of the day, 8 AM through 6 PM, resting or sleeping.

12. *Social Facilitation of Eating Behavior in Young Opossums*

Another behavior in which opossums have been compared with other animals is that of social facilitation of eating. This type of behavior has been observed in fish (52), rats (18), dogs (25, 30, 31, 43, 44, 46), chicks (49, 50), and monkeys (19). Platt and James (41) did a study with a litter of 10 young opossums that had been removed from the mother's pouch and reared on a bottle until they were able to feed themselves. They had been removed from the pouch 25 days when the experiment began. The animals were fed together and separately for 10 days alternately. Food intake was determined by weight before and after each test. Food intake under group feeding significantly exceeded that under individual feed conditions ($p < .001$). The amount of food intake increased greatly during the first few days of group feeding. This may have been attributable to the increased aggression in the animals at this time, or it may have been due to some form of secondary reinforcement, which seems to be the case of puppies (31).

13. *Double Alternation Problem*

The only type of learning the opossum has been unable to solve in the University of Georgia experiments is that of the double alternation problem.[1] In this type of learning, the animal is required to make two complete circles on the right side of a maze and then two complete circles on the left side to get to food. The animal could not solve this after many repetitions. It was able, however, to circle the right side one time and then the left side one time to get food without difficulty. The double alternation problem has been difficult for all lower animals. Raccoons (24), cats (35), and dogs (36) are all able to learn a single RRLL sequence, but cannot go beyond. The monkey seems to be better at solving the double alternation problem (14).

C. Discussion and Conclusion

In the above studies on the behavior of the opossum, it is found that in general the animal has been tested by methods used with other animals. In terms of the phylogenetic scale, the opossum has been considered near the bottom just above the platypus in the series. As the scale ascends through the various animals to man, and as the brain is enlarged, behavior is supposed to become more complex, learning takes place with ease, and

[1] James, W. T. Unpublished report.

adaptation to more complex situations becomes possible (51). In all the tests, however, the opossum seems to be adjusting with little difficulty and in many cases, better than animals above it in the phylogenetic series. The notion that the opossum was an entirely "dumb" animal, as proposed by all the early writers (20) and assumed by all hunters, does not seem to be borne out. All researchers who have worked with the animal have been surprised at its ability to perform in the usual testing techniques. Either the enlarged brain in the higher phylogenetic series does not have any great influence on learning, or the tests used do not indicate the significance of the complex nervous system. It is highly probable that the learning of these relatively simple problems involves mainly the lower brain systems and that the cortex is not involved at all. Experiments have indicated that simple organisms are capable of learning (10). Fish with no forebrain at all can also learn rather complex behaviors (1, 34). Mammals with their entire cortex removed also have been capable of learning simple discriminations (22).

It has been emphasized by Hodos and Campbell (21) that the idea that all animals can be arranged along a continuous "phylogenetic scale," with man at the top, is inconsistent with the present view of animal evolution. They state that it would be better to compare animals within the same line of descent, rather than to compare those on different limbs of the tree, as comparative psychologists have been doing. Each animal on every part of the evolutionary scale has its own structure and special adjustment mechanisms, and it is capable of learning to survive within its own environment. It is extremely difficult to place the different animals within the same type of

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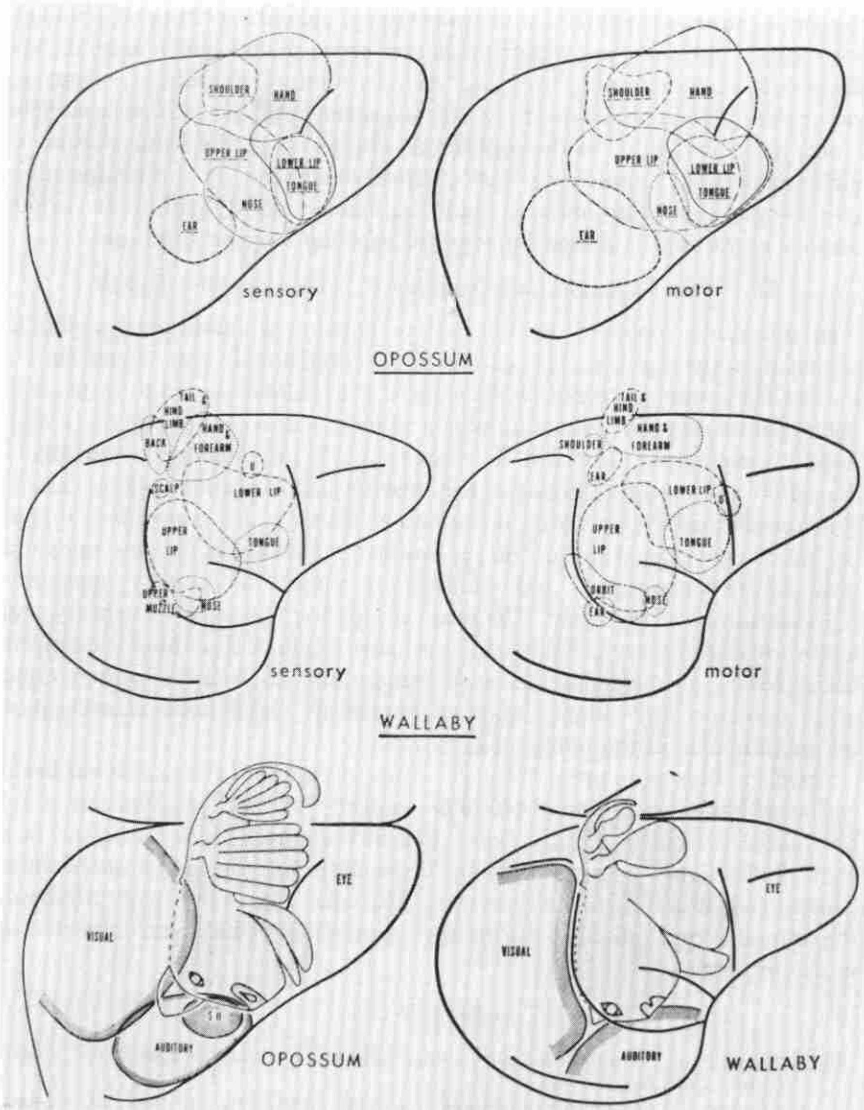
FIGURE 3

Sensory and Motor Representation in the Cerebral Cortex of the Opossum and Wallaby

Drawings show the neocortical surfaces of the right hemispheres with the frontal lobe to the right. Fissures are indicated by heavier lines. The inferior border of the hemisphere sloping down from the frontal lobe is the rhinal sulcus in each.

Top: Opossum. Sensory centers for selected body parts and motor centers. Note the correspondence of locations. Middle/Wallaby. Sensory and motor centers. "Upper muzzle" means the dorsal portion of the snout between nose proper and the eyes; "orbit" refers to eye closure; "U" indicates a small "upper lip area" separate from the main area.

Bottom: Homunculus-like picture of sensorimotor body representation in the opossum and wallaby. Above the lateral aspect of each hemisphere is a partial outline of the adjacent medial aspect which contains tail and hindlimb representations. The borders of visual and auditory areas are indicated. The small second somatic area in the opossum is labeled "S 11." Stimulation in the region labeled "eye" gives responses from the eye (from "Cerebral Cortex: A Sensorimotor Amalgum in the Marsupialia," Lende, R. A., *Science,* Vol. 141, pp. 730-732, Fig. 1, 23 August 1963. Copyright 1963 by the American Association for the Advancement of Science. Reprinted with permission).


SHOULDER
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sensory
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tests and compare them. It is more profitable to take the attitude of Schnierla who suggested that we "contrive to understand how each animal type functions as a whole in meeting its surrounding conditions, what its capacities are like and how they are organized" (45, p. 245). It would be much more revealing to do continuous studies with the same animal in different settings, natural as well as those contrived by the comparative psychologists, and learn more about its adjustment ability within the various sensory areas and its motor capacity for meeting varying situations.

D. The Generalized Nature of the Opossum Brain

In the study reporting an attempt to develop a conditioned avoiding response of the foreleg and rearleg in the opossum it was stated that a specific leg action could not be developed. The animal tended to respond to the signal by repeated leg action plus a general action of the total body with stepping movements involved. The dog is able to raise one leg specifically to the signal and hold the foreleg in the raised position until the signal ceases. This inability of the opossum to respond as does the dog is probably due to the more generalized nature of the brain of the animal. In the opossum brain, there is a complete and coincident overlap of the sensory and motor representations of the body. The brain of the dog has separate sensory and motor areas and there is not as much generalization of the stimulation of the brain. Figure 3 shows how the sensory and motor areas of the brain overlap in the opossum and wallaby, another marsupial. The bottom pictures show the homunculus in the opossum and wallaby (39).

Another study emphasizing the generalized nature of the marsupial brain is that of Nider and Randall (40) who showed that electric potentials could be recorded from practically every area of the cortex from the sound of a click. It is highly possible that since the action of the opossum brain is generalized, it is difficult to determine just what aspect of the environment the animal is responding to during the various tests it has been subjected to in experiments.

References

1. Bernstein, J. J. Brightness discrimination following forebrain ablation in fish. *Exper. Neurol.*, 1961, **3,** 297-306.
2. Bitterman, N. E. Phyletic differences in learning. *Amer. Psychol.*, 1965, **20,** 391-410.
3. Bombardieri, R. A., Jr., & Johnson, J. I. Daily activity schedules of captive possums. *Psychon. Sci.*, 1969, **17,** 125-126.
4. Cone, A. L., & Cone, D. M. Operant conditioning in the Virginia Opossum. *Psychol. Rep.*, 1970, **26,** 83-86.
5. Cone, D. M. Circadian locomotion activity in the Virginia Opossum. *Bull. Psychon. Soc.*, 1973, **1,** 13-14.

6. CONE, D. M., & CONE, A. L. Cage activity in the Virginia Opossum. *Psychon. Sci.*, 1968, **10,** 259-260.
7. DEMBER, W. N. Response by the rat to environmental changes. *J. Comp. Physiol. Psychol.*, 1956, **49,** 93-95.
8. DOOLITTLE, R. H., & WEIMER, J. Spatial probability learning in the Virginia Opossum. *Psychon. Sci.*, 1968, **13,** 191.
9. DUFORT, R. H., GUTTMAN, N., & KIMBLE, G. A. One-trial discrimination reversal in the white rat. *J. Comp. Physiol. Psychol.*, 1954, **57,** 248-249.
10. EISENSTEIN, E. M. The use of Invertebrate Systems for the studies on the basis of learning and memory. In G. C. Quarton, T. Melnechuk, & F. O. Schmitt (Eds.), *The Neurosciences*. New York: Rockefeller Univ. Press, 1967.
11. FINK, H. K. Mind and Performance. New York: Vantage Press, 1954.
12. FRIEDMAN, H. Color vision in the Virginia Opossum. *Nature*, 1967, **213,** 825-826.
13. FRIEDMAN, J., & MARSHALL, D. A. Position reversal in the Virginia Opossum: Evidence of the acquisition of learning set. *Quart. J. Exper. Psychol.*, 1965, **XVLL,** 250-254.
14. GELLERMANN, L. W. The double alternation problem. I. The behavior of monkeys in a double-alternation maze. *J. Genet. Psychol.*, 1931, **39,** 50-72.
15. ———. Chance orders of alternating stimuli in visual discrimination experiments. *J. Genet. Psychol.*, 1933, **42,** 206-208.
16. GLICKMAN, S. E., CLAYTON, K., SCHIFF, F., GURITZ, D., & MESSE, L. Discrimination learning in some primitive animals. *J. Genet. Psychol.*, 1965, **106,** 325-335.
17. GUTHRIE, E. R. The Psychology of Learning (rev. ed.). New York: Harper & Brothers, 1952.
18. HARLOW, H. F. Social facilitation of feeding in the albino rat. *J. Genet. Psychol.*, 1932, **41,** 211-221.
19. HARLOW, H. F., & JUDKIN, H. C. Social behavior of primates: 1. Social facilitation of feeding in the monkey and its relation to attitudes of ascendance and submission. *J. Comp. Psychol.*, 1953, **16,** 171-185.
20. HARTMAN, C. G. Possums. Austin, TX: Univ. Texas Press, 1952.
21. HODOS, W., & CAMPBELL, C. B. G. *Sala Naturea:* Why is there no theory in comparative psychology? *Psychol. Rev.*, 1969, **76,** 337-350.
22. HOREL, J., BETTINGER, L., ROYCE, J., & MEYER, D. R. Role of neocortex in the learning and relearning of two visual habits by the rat. *J. Comp. & Physiol. Psychol.*, 1966, **61,** 66-78.
23. HUGHES, R. N. Spontaneous alternation and response to stimulus change in the ferret. *J. Comp. & Physiol. Psychol.*, 1965, **60,** 149-150.
24. HUNTER, W. S. The behavior of raccoons in a double alternation temporal maze. *J. Genet. Psychol.*, 1928, **35,** 374-388.
25. JAMES, W. T. Social facilitation of eating in puppies after satiation. *J. Comp. & Physiol. Psychol.*, 1953, **46,** 472-478.
26. ———. The behavior of the opossum in the Guthrie-Horton Puzzle Box. *J. Genet. Psychol.*, 1955, **87,** 203-206.
27. ———. Conditioned responses in the opossum. *J. Genet. Psychol.*, 1958, **93,** 179-183.
28. ———. Behavior of the opossum in the Fink Arrow Maze. *J. Genet. Psychol.*, 1959, **94,** 199-203.
29. ———. A study of visual discrimination in the opossum. *J. Genet. Psychol.*, 1960, **97,** 127-130.
30. JAMES, W. T., & CANNON, D. J. Variation in social facilitation of eating behavior in puppies. *J. Genet. Psychol.*, 1955, **87,** 225-228.
31. JAMES, W. T., & GILBERT, T. F. The effect of social facilitation on food intake of puppies

fed separately and together for the first 90 days of life. *Brit. J. Anim. Behav.*, 1955, **111,** 131-133.

32. JAMES, W. T., & MCFARLAND, J. A study of form discrimination in the opossum. *J. of Psychol.*, 1966, **64,** 193-198.

33. JAMES, W. T., & TURNER, W. W., III. Experimental study of maze learning in young opossums. *Psychol. Rep.*, 1963, **13,** 921-922.

34. KAPLAN, H., & ARONSON, L. R. Function of forebrain and cerebellum in learning in the teleost, *Tilapia Heudelotte Macrocephalia. Bull. Amer. Museum Nat. Hist.*, 1969, **142,** 141-208.

35. KARN, H. W. The behavior of cats on the double alternation problem in the temporal maze. *J. Comp. Psychol.*, 1939, **27,** 201-208.

36. KARN, H. W., & MALMUD, H. R. The behavior of dogs in the double alternation problem in the temporal maze. *J. Comp. Psychol.*, 1939, **27,** 461-466.

37. LANGWORTHY, O. R. Correlated physiological and morphological studies of the development of the electrical response areas in the cerebral cortex of the opossum. *Carnegie Inst. Washington, Contrib. to Embryol.*, 1927, **19,** 149-175.

38. LASHLEY, K. S. Brain Mechanisms and Intelligence. Chicago: Chicago Univ. Press, 1929.

39. LENDE, R. A. Cerebral cortex: A sensory motor malgum in the marsupalia. *Science,* 1963, **141,** 730-732.

40. NEIDER, P. C., & RANDALL, W. Sound evoked potentials in neurocortex of unanesthetized opossums. *Science,* 1964, **144,** 429-430.

41. PLATT, J. J., & JAMES, W. T. Response to stimulus change in the opossum. *J. of Psychol.*, 1967, **67,** 85-89.

42. ———. Social facilitation of eating behavior in young opossums; group versus solitary feeding. *Psychon. Sci.*, 1966, **6,** 421-422.

43. ROSS, S., & ROSS, J. G. Social facilitation of feeding behavior in dogs: I. Group and solitary feeding. *J. Genet. Psychol.*, 1949, **74,** 97-108.

44. ———. Social facilitation of feeding behavior in dogs: II. Feeding after satiation. *J. Genet. Psychol.*, 1949, **74,** 293-304.

45. SCHNIERLA, T. C. Levels in the psychological capacities of animals. In Sellers, R. W., McGill, V. H., & Farber, M. (Eds.), *Philosophy of the Future*. New York: Macmillan, 1949.

46. SMITH, W. E., & ROSS, S. The social behavior of vertebrates: Review of the literature (1930-1950). *Psychol. Bull.*, 1952, **49,** 598-627.

47. SMYTH, R. H. Animal Vision. New York: Thomas, 1961.

48. TILLEY, M. W., DOOLITTLE, J. H., & MASON, D. J. Spontaneous alternation in the Virginia opossum. *Psychol. Rep.*, 1966, **19,** 593-594.

49. TOLMAN, C. W. Social facilitation of feeding behavior in domestic chics. *Anim. Behav.*, 1964, **12,** 245-252.

50. TOLMAN, C. W., & WILSON, G. F. Social feeding in domestic chicks. *Anim. Behav.*, 1965, **13,** 134-142.

51. WALUNIS, S. The nature of comparative psychology. In R. H. Water, D. A. Rathling-Shafer, & W. E. Caldwell (Eds.), *Principles of Comparative Psychology*. New York: McGraw-Hill, 1960.

52. WELTY, J. C. Experiments in group behavior in fishes. *Physiolog. Zool.*, 1934, **7,** 85-128.

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