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HABIT FORMATION AND HIGHER MENTAL CAPACITIES IN ANIMALS

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One sometimes wonders what animal would make comparative psychology possible if the rat did not exist. In earlier work, such

as that of Thorndyke, the cat held its place; but in the present review, of sixteen reports concerned in one way or another with learning, thirteen, including all but one of the major articles, make use of the rat.

Peterson publishes two reports (14, 15), both based upon the same work with rats, and attempting to analyze the processes concerned in learning the maze. In this work, two pairs of mazes were used. The two members of the easier pair were alike except that all blind alleys in the one member were relatively shortened compared with the other. The two members of the more difficult pair were alike except that in the one a part of the blinds were relatively shortened, in the other the remaining blinds were relatively shortened. The rats were divided into groups, and each group learned one member of each pair of mazes, so that each maze was learned by a previously untrained group and also by a group that had learned one of the other pair. Peterson tabulates the results in a way to bring out several uniformities. As learning progressed, there was a rapid decrease in the proportion of returns to forward runs (toward the food box) upon emergence from a blind alley. In cases of shortened alleys which are eliminated more rapidly than the longer ones, returns are eliminated still more rapidly. Any given alley is eliminated more easily when shortened than when used full length. In the process of elimination of a cul de sac, one finds a transition from complete entrances to only partial entrances and then only starts into the ally or hesitations. Blinds near the beginning were entered more frequently and were more difficult to eliminate than those nearer the food box; the percentage rate of elimination was greater in the latter. The percentage of returns to total entrances in the first two trials was greater in alleys at the beginning than in those at the end. Returns as well as entrances persisted longest in the case of alleys farthest from the food box. In the larger maze, returns from shortened alleys in the first two trials were the same as from the longer alleys; in the smaller maze returns were distinctly less from the shortened alleys. Returns by untrained rats in the first two trials in the larger maze were about 40 per cent. of the entrances. There is probably an equal chance of return or forward run at first, but learning soon modifies the matter. Rats that had been trained in one of the other pair of mazes made less returns. In training, an animal rapidly gains the ability to avoid returns and carries this over to other mazes.

Peterson thinks the laws of frequency and recency are entirely

inadequate to explain several of these facts. In his second article, he tabulates entrances to blinds, returns, etc., as though determined by flipping coins, on the basis of pure chance. This shows why we find more entrances and more returns near the beginning than near the end. On the basis of chance, the number of times an animal will pass a given blind, with or without entrance, in a forward direction will exceed the number of times he will enter it from both directions combined and will still more exceed the times he will pass in a return direction. The difference, or excess, is absolute, and therefore, greater relatively in the case of the alleys near the food box. Peterson believes this explains the learning progressively backwards from the food box. The explanation is limited however by the fact that frequency alone would tend to stereotype the first acts in the maze, and by the fact that his rats did not follow expectations based on frequency and recency in their learning. Other factors are necessary to account for the selection that makes learning possible. Here Peterson brings in his principle of completeness of response. The animal as a unitary organism is reacting to a whole situation. The organism is under the influence of a great number of stimuli from inner organic processes and its own responses and from external conditions. These occur in series, but there are cumulative effects which hold over into the final results, and all acting together are supposed in some way to control the associations formed, to direct the energy of the animal into the "most consistent channels," so that the "consistent acts" survive in time over all others. Visceral factors are thought to play a prominent part in this process of selection. The holdover impulse to take the other path on passing any junction, making the activity incomplete and hesitant is another specific factor emphasized.

Carr, in a series of three articles (2, 3, 4), reports the results of experiments concerning the dependence of maze habits on a variety of sensory conditions. Most of the mazes used were of the usual type, almost watertight and covered by closely fitting glass. In some experiments, a small enclosure made of several thicknesses of canvas was used over the maze. The canvas was stretched over the top and hung loose at the sides, so that any side could be raised at will. An electric light was suspended at the top for illumination, or, in other cases, only the daylight passing through the canvas was used.

Carrying the rats by a variable route from the cage to the maze produced no effect on either normal or blind animals. The same

was true of variations in the method of handling, introducing conditions of dizziness, etc. After the maze was learned, the cage was moved to a different position in the laboratory, but without changing its original cardinal orientation. Normal rats, blind rats and anosmic rats were all more or less affected. Covering the living cage with canvas, on the other hand produced no effect. The cage was rotated with reference to the cardinal directions but kept in the same location. Normal rats were considerably disturbed in runs of the maze if both maze and cage were uncovered; the effect was doubtful if either cage or maze was covered. Blind animals were more affected than the normal, anosmic animals were less affected than normal. The degree of hunger affected all rats. Cleansing the maze after it had been learned disturbed normal and blind animals, but not the anosmic. After the maze had been learned, the canvas enclosure was placed over it; there was no effect. Two other groups learned the maze with the canvas enclosure over it. In the first place, the enclosure was partly open, giving poor daylight illumination. Removal of the canvas then caused no change in behavior. In the second place, the electric light was used for illumination during learning. Removal of the enclosure then affected part of the rats. Blind animals were not disturbed. If the maze was learned with the canvas covering in place and with only the reduced daylight illumination, the normal rats were then disturbed by turning on the electric light. Another group learned an uncovered maze placed next to an open window. The window was then covered. Most animals (normal) were disturbed. If the experimenter maintained a constant position with reference to the maze during learning and then changed position to the opposite side of the maze after a rat was put into the maze, normal animals were disturbed in greater or less degree, blinds were not. The maze was learned with the canvas covering in place, and illuminated by the electric light. Rotation of the enclosure alone then produced no effect. When both maze and enclosure were rotated, however, the animals were somewhat disturbed, and did not adapt sufficiently to prevent similar disturbances in successive rotations. Blind rats showed more effect in this test than the normals. If the maze was learned with the canvas covering open on one side, and without the electric light, and if the open side was then closed and another side opened, all rats, normal, anosmic, and blind were moderately disturbed. Similar disturbance was caused to normals by moving the uncovered maze, after it had been learned, to a new

position in the laboratory, but without changing its relations to cardinal directions. This test had no effect upon the blind animals. The maze without canvas covering was learned and then rotated. All normals were markedly confused, but were able to adapt to successive rotations and finally to eliminate the disturbance. If the room was darkened by means of window shades, there was less disturbance. Blind animals were also confused, but to a less degree than the normals; they did not adapt so well as normals. A sideless maze was learned by normals and then rotated and the confusion was much greater than with the standard maze. There was even disturbance when a maze without culs de sac was learned and then rotated. Rotation of a standard maze from day to day during learning interfered seriously with learning by normals, but had less effect with blinds. A heterogeneous environment was better than a uniform environment for learning in normals.

The effects of these various tests on different animals were not at all uniform. In nearly every case some animals were immune to the altered conditions. A given animal might be affected in one trial and not in another, or disturbed by one test and not by another. Blind rats were individually more variable than normal, and, when affected by the alterations, were liable to be more confused than normal; they were also less liable to adapt to the alterations than normal. Vision, on the whole, aided in learning the stationary maze. The blinds were not so much affected by rotating the maze from day to day during learning as the normals. The normal rats were susceptible to the alterations in a greater per cent. of the cases than the blind; they were more sensitive. Carr thinks this was due to a distractive effect of visual changes rather than to any directive force of vision in the maze habits. He explains the advantages of vision in the rat as due to its tonic and stimulative effect upon organic processes, and consequent promotion of learning ability, together with a deleterious effect of the operation in case of the blind.

Carr also reports an experiment on the habit of simple alternation in rats (1). In his apparatus, two alleys led from in front of the animal to a food box and the exit from either to the food box could be blocked. The entrances to the alleys were six inches apart and, as the animal approached them, first in one trial the right, in the next trial the left was the one with open exit to the food. The animal's problem was then to learn to go to the alley entrances alternately in successive trials. All animals used were able to form the habit. Variations were introduced to determine

what cues the animals used in controlling the successive reactions. They were placed in the starting-box in different positions, even in positions the reverse of that usually used in the training, and they were handled at times by a different operator. Reversing the positions and handling by another operator disturbed part of the rats; but these novel conditions were quickly adapted to and on the whole the animals continued to make progress in spite of the variations. Making the correct initial choice of each day's work was the most difficult matter, and this should not be true if the cue were given by position in the starting box. All these facts indicate that the rats were not reacting to the way they were handled. The normal time between trials during learning was 16.5 seconds. After learning, this time could be increased to about 60 seconds before the habit began to fail. If, after a few seconds to eat, the animals were taken out of the food box and placed on the table under novel conditions so that their motor attitude was lost, then replaced in the starting box after 50 seconds, they still made about 70 per cent. correct reactions. We conclude that the rats are controlled in part by sensations from the preceding act, in part by the distinctive motor attitude which was normally held during delay. The rat may then form an association between a sensory stimulus and an act, which are separated by an interval of 16.5 seconds, and, after learning, this interval may be lengthened to about 60 seconds before the habit fails. (The reviewer would suggest that the learning may be assisted, so far as the evidence shows, by the motor attitude which bridges the gap.) The evidence indicates that some animals depend more on the motor attitude, others more on the sensory results of the preceding act.

A most interesting paper is that by Thompson on learning in the snail (16). The snails were tamed before the experiments began, so that they could be moved from dish to dish and worked upon without retracting and expelling the air from the lung. When food is applied to the mouth parts of such a snail, one obtains a response consisting of a series of movements which may be counted and timed. This response probably only occurs, at least for practical purposes, as a result of external stimulation. The normal frequency and range of response were first determined. An apparatus was then constructed by means of which a uniform pressure could be applied to the foot at the same time the food stimulus was applied to the mouth parts. Tests by the pressure alone showed that it brought out no responses. When the pressure and food

stimuli were applied simultaneously, there was at first an inhibition of the normal responses to the food. There was then a gradual rise of the response curve, though, on the whole, the average percentage of responses and the average number of reactions (movements) per response was less than in the normal food series. The individual reaction was accelerated. After this training, the pressure stimulus, which formerly had given no response, was applied alone and responses were obtained and continued to be given in trials extending over a period of 96 hours after learning, then suddenly ceased. Training was then renewed and responses obtained with food and pressure approximately equal to the normal with food stimulus alone. The experiments show definitely that the animal can adapt (becoming tame, disappearance of inhibitory effect of pressure stimulus) and can form simple associations between the pressure and the food stimulus—response reflex. The snails also formed an associative connection between a tactile stimulus and an electric shock which was given soon after the tactile stimulus unless the animal turned and took the alternative path in response to the stimulus. The tactile stimulus alone did not lead to turning, but the animals learned to turn in response to it in a large part of the cases. They did not succeed, however, in learning a simple labyrinth including one choice with a reward for the successful choice. Also they did not form a connection between a weak tactual stimulus and a much delayed shock, but the effectiveness of the tactual stimulus as such was doubtful in this case.

Two papers are concerned specifically with the transfer of training. The first is by Wylie (21) and deals with transfer in a relatively simple situation. He wishes to keep the response constant and vary the stimulus under proper control. A stimulus, which had been shown to be the dominant one controlling a given response, was removed, and another, which had not been present, was substituted for the first so that the second became dominant instead of the first. Rats were used in the experiments. The first part of the experiment was not successful for the purpose, probably on account of inaccurate localization of sounds under the conditions, and need not be described in detail. We may note, however, that the rats could learn to use movements of the experimenter, probably sensed visually, as cues to control acts. In the apparatus used in the second part of the experiment, two alleys were open to the animal and led to a food box, but the exit from either to the food could be closed. Lights were placed at conspicuous places in

each alley and could be separately controlled. Electric sounders were similarly used, and metal strips on the bottom made it possible to give electric shocks whenever desired. The animal was released and allowed to enter either alley. In part of the trials he was then given a stimulus (light, sound, or shock as the case might be) in response to which he was required to turn back in order to obtain food through the other alley. In the remainder of the trials, he was allowed to proceed to the food through the first alley. Rats learned the act in response to one stimulus (for instance, light) and were then transferred to the use of one of the other stimuli (for instance, sound or shock) with or without an intervening period in which the first and second stimuli are given together. The original learning curves in the case of each stimulus showed usually a period of no learning followed by a sudden jump to practically perfect response. The period of non-learning might be due to lack of attention to the stimulus (probably true with sound and light) or to emotional disturbance (as in shock). The non-learning period was longer and the curve was more irregular in the case of sound than with the other stimuli. The greater difficulty in controlling sound from external sources probably contributed to this. The writer thinks these learning curves are the first animal curves of this nature to be reported. The reviewer can see no essential difference between them and some of Thorndyke's curves from monkeys except that the conditions with the monkeys were more difficult. In all cases, after the response had been learned in connection with one stimulus, it could be relatively easily transferred to connection with either of the other stimuli; and this process was nearly always helped by putting in an intervening period in which the first and second stimuli were used together.

The second transfer article is by Webb (19) and is concerned with transfer in a relatively complex situation, maze learning. Rats and humans were used. A series of the usual form of mazes were used with the rats; similar patterns of pencil mazes were used with the humans. In the first experiment, five groups of rats learned a maze *A*, following which one group learned *B*, another *C*, another *D*, another *E*, another *F*. Similarly, three groups of humans learned maze *A* and then each group learned one of *B*, *C*, or *D*. In the second experiment, five groups of rats learned *B*, *C*, *D*, *E*, and *F* respectively, and then all learned *A*; three groups of humans learned *B*, *C*, and *D* respectively, and then all learned *A*. Transfer effects were measured by trials, errors and time. It was found that

the transfer was positive in all cases. However, transfer may be complex, showing both positive and negative elements. Thus mazes *A* and *F* were so related in one portion that learning *A* interfered with *F* in that portion, though the total effect was positive. In the first experiment there was a positive correlation between the degree of transfer and the difficulty of the second maze as measured by learning of untrained animals. In the second experiment there was a positive correlation between degree of transfer and the difficulty of the first maze as measured by learning of untrained animals. But the reviewer wishes to insert that the differences of the compared mazes were greater where transfer was from the single maze to the compared mazes, than when transfer was from the compared mazes to a single common maze. There was a positive correlation between the amount of transfer and the similarity of the two mazes as rated by a number of individuals. Transfer effects were similar for the human and animal groups. There was a positive correlation between the results according to any two of the three criteria of measurement; it was highest between time and errors. The locus of transfer is on the average confined to the first five trials. Transfer on the whole exerts a somewhat greater effect upon the tendency to retrace than upon the tendency to enter blind alleys.

After learning maze *B* and then *A*, animals were required to learn *B* again. This second learning of *B* was compared with the results with a group which learned *B*, then waited during the interval the first group was used on *A*, then relearned *B*. Likewise *C—A—C* was compared with *C—C*, etc. Likewise *A—B—A*, *A—C—A*, etc., were compared with *A—A*. There was no correlation between learning and relearning records of different individuals. The maze which required the greater effort to master was retained longest. There was greater disintegration of the first maze habit where a second maze was interpolated than was due to a mere lapse of time. Some subjects were affected by the retroactive influence, others were not; humans were affected more than rats. The easier is the interpolated maze, the greater is the resulting negative retroaction. There is a negative correlation between positive transfer from the first to the second maze and the negative retroaction of the second upon the first. Such retroactive effects are explained on the basis of a transfer from the second to the third learning.

Dodson (7) studied the relative values of reward and punishment in forming habits. He used rats as subjects. In the appa-

tus, as the rat was placed in the entrance box, it faced a light and a darkened electric box. In one set of experiments, if the animal chose the light box, it could pass through and back to the nest; while if it chose the darkened box it was given an electric shock after entering and was forced to return through the entrance box and thence through the light box to the nest. In the other experiment (that with reward), if the subject chose the light box, it could pass through and to the food; while if it chose the darkened box, it found the door closed and had to return through the entrance box and thence through the light box. The usual precautions were taken against place associations. Four different strengths of shock, 60, 75, 115, and 150 units respectively were used; also four degrees of hunger produced by 24, 31, 41, and 48 hours respectively without food. With each stimulus there is a most favorable intensity: the stronger the stimulus, the more vigorous the activity and better the learning up to a certain point. If the strength of shock passes beyond this point, learning is interfered with by distracting excitement. If starvation is lengthened beyond the most favorable time, the animal probably has sensations of hunger but is not eager for food. The most favorable intensity of shock under the conditions was found to be 75 units. In the case of hunger, the most favorable period of starvation with animals 78 days of age was found to be between 41 and 48 hours. The shock, under the conditions of this experiment, was more favorable to learning the connection than was hunger.

Watson (18) wished to test the efficiency of satisfaction-dis-satisfaction as a selective agent in trial and error learning. He tried to find whether they work by a retroactive stamping-in or -out effect upon immediately preceding activities. He constructed a problem box in which a food receptacle was located and in which the animal (rat) was confined after he had succeeded in entering. The food receptacle was covered by a perforated lid which could be held in place or removed by the experimenter at will. One group of animals learned the box in the usual way, obtaining food immediately on entering. In the case of another group the lid was held on so that they did not get the food until 30 seconds after entering, during which interval, of course, the animal went through many and varied activities. In spite of this the curves of learning of the two groups were alike. Watson is inclined to conclude that the satisfaction of obtaining food was not a selective factor. Why, he asks, should not the later random movements made after the animal

entered the box be the activities to be benefited by the better condition of the organism?

Dunlap (8) suggests that possibly pleasure-displeasure are connected with changes in internal secretions, either from a gland or glands or from some tissue whose primary function is not secretion. He further suggests that an activity may leave some parts of the nervous arc in such a chemical condition that these secretions a little later may "fix" the arc: hence selection by results in trial-and-error learning.

Lashley (11) used rats as the subjects and the circular maze as the problem to study the effects of strychnine and of caffeine upon the rate of learning. The drugs were given by subcutaneous injections. Some animals received injections of water, some received strychnine sulphate, some received caffeine. Strychnine caused an acceleration of learning if given in large enough doses to cause observable alterations in muscular tonus, tremor, etc. Caffeine regularly interfered with learning. The movements of the strychninized rats were retarded, the movements of the caffeinized rats were accelerated compared with the normal. The caffeinized animals often seemed in a high state of excitement. After the habit had been perfected, strychnine increased and caffeine decreased the accuracy of performance. The advantageous effect of strychnine is probable correlated with reduction of synaptic resistance.

Lashley and Franz in two papers (9, 12) report the results of unusually valuable work on the relation of habit formation and cerebral (more especially cortical) functions in the rat. Two sorts of apparatus were used for the tests of habits: one was a simple maze with one choice; the other was a problem box which had to be opened by tilting an inclined plane on the top of the box, then entered through the door on the side. It was found that complete destruction of the cortex above and in front of the knee of the corpus callosum did not interfere with retention of the simple maze habit which had been learned before the operation. In fact this habit persisted even when, in addition to the frontal poles, a great part of the dorsal convexity was removed, and apparently no part of the cortex in front of the caudal end of the corpus callosum and above the level of the floors of the lateral ventricles is concerned with the retention of this habit. One animal with the frontal poles and nearly all the dorsal convexity (including all that is directly excitable and usually classed as motor) destroyed, and with the right corpus striatum and fornix degenerated with permanent

spasticity on the left side, still succeeded in learning the simple maze in a manner nearly normal. Another with "destruction of all the cortex above and in front of the corpus callosum and lateral to the left lateral ventricle with partial degeneration of the right and complete degeneration of the left caudate nuclei; destruction of the fornix and injury to the thalamus on the right" was unable to learn the maze but did form simple habits of stereotyped response. A simple habit may then be learned after destruction of all the frontal, temporal, parietal, and much of the orbital surface of the cortex, leaving only those portions usually said to be visual, auditory, or olfactory in function. In the case of the problem box, on the other hand, complete destruction of the frontal poles causes loss of the habit, though the temporal and parietal areas may be destroyed without injuring the habit. Some considerable portion of the frontal poles must be preserved, but it may be any given portion; no particular portion is necessary. It seems that such a habit is mediated not by a single chain of neurones, but by a whole set of arcs, using all parts of the frontal poles, and the preservation of any considerable part is sufficient to retain the habit. The problem box habit was reacquired by some animals, however, after nearly or quite complete destruction of the frontal poles.

Kempf (10), experimenting on six monkeys, found two which showed decided right-handedness, one which showed decided left-handedness, and three which showed less definite left-handedness. Each was trained by allowing it to reach for food and preventing it getting the food unless the hand opposite to the normal tendency was used. All learned the new habit, and all but one retained it after three or four months without intervening training in the test.

White (20) found fish able to form associations with color stimuli, jarring the tank, and movements of the investigator; but the animal was not able to learn to discriminate patterns. The associations of the fish, according to her results, are fairly permanent, but are simple, are not easily modified when once established, and do not allow fine discrimination.

Yoakum (22) describes similar cases of positive response to a lighted area by a cow and by a man. The response was entirely automatic. An emotional state was the result when the smooth response was interrupted by an avoidance reaction in the man.

Marshall (13) objects to Watson's behaviorism and thinks it simply abandons the study of psychology altogether. He also objects to Bode's treatment of consciousness. De Laguna (5, 6)

criticizes the dualistic position of Washburn's animal psychology with its attempt to use experimental facts to infer by analogy the presence or absence of peculiarly conscious states; though, fortunately, the treatment of actual scientific problems and results by the "dualist" and "behaviorist" differ for the most part only in the mode of formulation. Such mechanical behaviorists as Bethe are also criticised and the writer wishes for a proper recognition of the fruitfulness of introspective investigations without the extreme of dualism. Washburn replies (17), but such articles cannot well be presented in a review and those interested in the general theoretical aspects of the subject should read them.

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SPECIAL REVIEWS

Orthogenetic Evolution in Pigeons. Posthumous Works of C. O. Whitman. Vol. 3, *The Behavior of Pigeons.* (Ed. by HARVEY A. CARR.) Washington: Carnegie Institution of Washington, Pub. No. 257, 1919. Pp. 161.

The "Behavior of Pigeons" bring together Whitman's observations on the instincts and habits of these birds. The material is grouped into three main divisions: the reproductive cycle, homing and other instincts, and instinct and intelligence. The first division includes nine of the thirteen chapters in the monograph. This division includes a reprint from Whitman's Woods Hole lectures and also an excellent editorial summary. The nature and interrelationships of copulation, nesting, egg-laying, incubation and feeding the young are presented in detail. Of these the first three may be absent without inhibiting the last two. Feeding however does not occur without previous incubation. Egg-laying and possibly display are the only elements of the cycle that necessarily distinguish the behavior of the two sexes. Valuable data on the synchronization of behavior in the sexes are given.

Drs. Craig and Riddle offer a chapter summarizing the work on voice and instinct in pigeon hybridization. The chief conclusion is that the crossing of two species gives intermediate voice behavior. The chapter is admittedly fragmentary, yet even so note should have been taken of the possible effects of social influence during the rearing of the birds. The data do not extend beyond the F_1 generation.

The instinct of homing is regarded as an outgrowth of the social (gregarious) instinct and of the love of home possessed in some degree by all pigeons. Specific cases of return are explained by the visual landmarks theory. The behavior characteristic