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AN EXPERIMENTAL STUDY OF THE MENTAL
PROCESSES OF THE RAT.

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The studies presented in this paper are concerned solely with the mental life of the white rat, the albino sport of the common pest, *mus decumanus*. The white rat exists, so far as I am able to learn, only in captivity, and so, though especially suited for laboratory study, may be expected to present some slight variation from its wild congeners. No apology is made, however, for this limitation, for the writer feels that at present the greatest need of Comparative Psychology is the careful description of the psychic life of special animal forms. Generalizations will come in due time.

Work of this kind has already been done by several investigators in various phases of comparative psychology, the most systematic studies of vertebrates being those of Dr. Thorndike in the Columbia laboratory, and of Dr. Kline in the Clark laboratory.¹

The chief difficulty of such experimentation lies in controlling the conditions of the problem without interfering with the natural instincts and proclivities of the animal, and thus distracting or deflecting its attention. "An animal should be made to do difficult things only in the line of its inherent abilities."²

¹Thorndike: Animal Intelligence, *Psy. Rev. Monographs*, No. 8. Kline: Methods in Animal Psychology, *Am. Jour. Psy.*, Vol. V, No. 2; Laboratory Course in Comp. Psy., *Am. Jour. Psy.*, Vol. V, No. 3. Morgan, Mills and others have, of course, made experiments of great value, but for the most part of a more informal character.

²Ernest Ingersoll: *Wild Neighbors*, p. 179.

The experiments described in this paper are a part of a series carried on in the Clark laboratory in the academic year 1898-99. Their primary purpose was to study the character of the associative processes of the rat; *pari passu* with which, however, would necessarily go a study of the general character of its intelligence as conditioned by its dominant instincts, structural and functional traits, affective life, etc., as well as by the form of the associative processes—indeed as basal to them. The word association is used broadly to cover all possible connections of mental elements as indicated by the activities of the animals. Wundt's definition of association as "ideational connections which do not exhibit the characteristics of the activity of logical thought" might serve in this case with the more general phrase "connections of mental elements" substituted for "ideational connections." Wundt's definition is useful as a description of the upper limits of association.

The experiments described fall into six groups. All of them bear upon the problem of the manner in which contiguous associations originate and are integrated; upon the persistence of such processes; and the factors entering into them. Other points studied are variability of the association after it is formed, recognition and discrimination, imitation, and individual differences.

The diary, extracts from which are contained in the following pages, was made while the observations were in progress, and so records the impressions while they were "hot." Interpretative conclusions, tentative in most cases, are advanced here and there. This method of presentation is believed to be the most fruitful under the circumstances.

GROUP I. This group of experiments was the original point of departure for all the succeeding experimentation. It was undertaken merely as a study in method in comparative psychology for the laboratory, based upon the general principles of such study as enunciated in the introductory section. The most definite point in view was to test the rat's peculiar modes of activity in the process of forming definite associations within the scope of its natural mental experience; the rapidity with which such formations are perfected; their stability and permanence, and, in general, to get a more accurate knowledge of the kind of intelligence possessed by the rat. It will be seen, then, that the aim was comparative in the exact sense, as well as structural. Indeed the structural aim was subsidiary.

The most natural motive to play upon in such experimentation is hunger. This furnishes the best dynamic for mental procedure. The rat is no exception to the reign of the nutritive impulse.¹ On the active side digging was selected as a

¹ I trust the reader will not "jump" to the conclusion that no other

characteristic instinctive activity in the free life of the rat—as was clearly apparent in the writer's Study of Psychic Development.¹

The apparatus used was a cubical box of 6-inch dimensions. The sides were of $\frac{1}{4}$ -inch wire mesh; the bottom of wood $\frac{3}{8}$ -inch thick; and the top of glass. In the front side of the bottom was a hole large enough to admit a rat. The bottom was raised $1\frac{1}{2}$ inches from the floor of the cage by strips of wood on the sides of the bottom. In experimentation the food was put inside the box, and sawdust was banked around the box to the top of the floor, completely concealing the entrance. This will be spoken of as Box I; two series of experiments were made with it upon two pairs of rats. The experiments were performed in the cages² where the rats were usually kept. At the regular time for feeding, Box I, containing food, was placed in the cage and banked up with sawdust. Before the experiments were begun Box I was left open in the cage for several days that the rats might become perfectly familiar with its appearance. Their timidity makes such precaution advisable.

Series I. Rats I and II (both females). The series consisted of 13 experiments, on successive days. The selected examples³ which follow show the results of the series. The notes were made always while watching the experiments.

Experiment 1. Both rats attacked the box at once. They crawled all over the box, and went round and round it monotonously. Sniffed continually. After an hour of persevering effort they began to get discouraged; their movements becoming haphazard and indifferent. One gave up and returned to the nest. The other, more frisky, soon began scratching about instinctively. The hole thus accidentally dug happened to be in the right place. The rat immediately poked its nose into the new opening which was not large enough to admit its head. It then ran away as if frightened, but soon returned, sniffed cautiously at the hole, dug away more sawdust, and then scampered away again. These acts were repeated several times, till a large opening was made. The rat then entered cautiously, snatched a piece of food and carried it into its hiding place in the corner of the cage. Time, 1 hr. 30 m.

motive would be workable. Hunger is merely the most fundamental and most surely-to-be-relied upon.

¹ *American Journal of Psychology*, XI, 1899, 80-100.

² Cage as follows: Dimensions in inches. Length, 20; height, 16; width, 16. Floor, back, and top of wood; front and one end of glass; other end, wire mesh ($\frac{1}{4}$ -in.) for ventilation. Floor is covered with sawdust.

³ A detailed account of the first five of this series may be found in Kline's article: Methods in Animal Psychology, *Amer. Jour. of Psy.*, Vol. X, No. 2, p. 277. I quote in part from that account.

Experiment 2. Actions similar to those of the preceding day, except that they spent more time near the place excavated yesterday, seeming to have located the right place indefinitely. After four minutes of frisking and fidgeting one began digging with a will, not stopping till the work was completed. As before, they did not enter at once, but frisked about nervously—peering into the hole, scuttling away and sniffing for some minutes. Time, 8 m.

Experiment 3. Rats began work immediately, and confined their efforts to movements about the right place. Sniffed around for a minute and a half, then one began to dig, and completed the task in one-half minute. No hesitation about entering. Time, $2\frac{1}{2}$ m.

Experiment 5. Only one rat came out. Approached the box leisurely, sniffing the air as she went. Stood erect, with fore-paws against the box. Suddenly dropped down and began digging. When half done, stopped, walked away, returned and finished the work. Entered and took food. Time, $3\frac{1}{2}$ m.

Experiment 13. Most of the useless movements have been dropped. There seems to be a pretty definite idea of what is to be done. Time, 30 sec.

The features of the series were the rapid reduction of the time required to get into the box, the elimination of most of the useless preliminary movements, and the apparent definiteness of the movements at the end of the series. The time required was reduced from 1 hr. and 30 m. the first day, to 8 m. the second day, and so on gradually to 30 sec. the last day. At the fifth trial, however, the associative process seemed very insecure. The rats had not learned to dig at exactly the right place, nor did they dig at all till they had examined the box several times; but at the end of the series they had definitely located the point of attack, and associated that with the appropriate movements, so that if *very hungry* they would begin immediately to dig in that spot. The nervousness relative to entering the box after the excavation had been made, so apparent the first few days, disappeared entirely about the sixth day. The actual time relations of the series are given in Table I.¹ It will appear from this table and from other tables that the time relation will not serve as an exact index of the definiteness and certainty of the mental process thus figured.² It does give, however, a general index, if the relation considered be that of one experiment to the whole series, not to the next consecutive experiment.

Series II. Rats III and IV. The conditions and apparatus were exactly as in Series I. Both rats were females.

¹ See tables at the end of the article.

² For this reason I have not plotted any time curves.

Experiment 1. The rats worked at intervals for 35 m., when they got the food. They dug very little at a time. At no time did they become aware that the sawdust was the obstructing object. They were not quite so vigorous in their efforts as I and II had been.

Experiment 2. They dug in in two and a half minutes.

Experiment 3. After the usual preliminary sniffing they dug in. The movements were not very vigorous, and they did not confine their efforts to the objective point. Rather, they dug promiscuously along the whole side of the box, showing that the place of entrance is not located.

Experiment 4. Secured the food in one minute.

Experiment 6. One rat went at once to the right spot and dug four or five strokes. Tried then to enter, but stuck half way. Withdrew head and finished the excavation in a most business-like way. Time, 30 sec. The other rat did no digging, but tried to steal her industrious comrade's hard-earned food. Failing in this she came to the hole, but did not enter. Ran back and again tried to steal, evidently not realizing at all the significance of the hole—or perhaps a safer suggestion would be that the certainty of the piece in the other rat's possession distracted her from making exploration. After about 1½ m. scuffling she came again to the box and got the remaining piece of bread.

Experiment 8. Did not begin work for nearly a minute. Then went directly to the right place. The sawdust was piled a little higher than usual. The "leading" rat went once around the box, as if looking for an easier place. Came back and dug in. Actual time, ½ m. The other rat tried, for several minutes, to steal her mate's food before going to the box.

Experiment 9. Delay of ten minutes before leaving the nest. Then dug in in a few seconds.

Experiment 10. Both rats very hungry. Hardly waited for me to close the box; sniffed and tried to get in while I was banking the sawdust. Into the box with a few strokes. Time, 10 sec. The second rat is not so sharp. First tried to steal the bread from her mate; then poked her head into the hole, but did not find the bread, as it was in the opposite corner. She then alternated for some minutes between fighting with her mate, and digging at the corner inside of which was the other piece of bread. This suggests that this rat does not associate the *whole of the box* with the food. It may be that the association in the case of the other rat is between *digging at a special place* and getting the food, the visual image of the box as a whole having a very unimportant rôle in the process. The second rat finally got the food from her mate. This one returned at once to the box and got the other piece.

Experiment 13. The "leading" rat instantly attacked the right place, and dug in with a few well directed strokes. Not a false or unnecessary movement. Time, 10 sec. The other rat stole her mate's bread. The latter returned immediately and got the second piece.¹

Experiment 18. Neither rat attempted to get the food. They walked idly around the box once or twice, then went to their nest and lay down.

Experiment 19. Rat III went immediately to work—apparently very hungry. She dug half-way in, and then paused and ran around to the side of the box, as if to see whether the food were there. Back, and in. Sniffed both pieces of bread; took the larger.

Examination and comparison of these two series of experiments, made under conditions as nearly identical as possible, yield some interesting results. (a) It was not remarked in the course of Series I, that only one of the rats had learned to perform the task. This was observed in the course of Series II, and proven after experiment 13. There is no doubt, however, that the same is true of the rats in Series I, as was confirmed later. The significant thing about this fact is the reflection it casts upon the imitative faculty of the rat. Rat IV must have seen Rat III make the excavation and enter for the food, but she did not imitate the action. The action and the end were not inferentially associated. This fact limits, but does not exclude imitation. (b) The time factor in the two series shows marked differences. Under identical conditions the rats in Series I required for experiment 1 more than double the time required by those in Series II—90 and 35 m., respectively; and a similar difference appears in following down the table, noting the relative celerity with which the association becomes definite and stable: in Series I the minimum time is 20 sec., reached in experiment 13; in Series II the minimum is 10 sec., reached in experiment 10, the minimum of Series I, 30 sec., being reached in Series II in experiment 6. (c) The immense importance of the first success is brought into relief by the drop in time from the first to the second experiment in both series, 90 m. to 8 m., and 35 m. to 2½ m., respectively. (d) The irregularity of the time factor after the rats had learned the task is noteworthy. In Series II, *e. g.*, the variation is from 10 sec. to 40 sec. after experiment 9, when the task was fully mastered. This variation is due to several causes, probably, the

¹ Being pretty well convinced that the same rat was doing the work each time, I now marked the rats so that they were easily distinguishable. I designate them hereafter III and IV, III being the one that had solved the problem.

most apparent of which are variations in appetite, and the normal "flightiness" and timidity of the rat.

GROUP II. In purpose and execution this group of experiments coincides with Group I. As, in that case, the end aimed at was a carefully controlled observation of the *modus operandi* of the rats in solving a problem easily within their capacity, and without inhibiting or distracting influences. The difference lies in the instinctive activity appealed to, gnawing instead of digging, and the adaptation of apparatus to that activity. There is also a further slight difference in the conditions, in the substitution of the new piece of apparatus, similar in appearance to that with which they were already familiar. This tests incidentally their power of recognition and discrimination—the same rats being used.

The apparatus used in this group, and designated Box II, was as follows: Form, material and dimensions, the same as Box I. The only difference is that the entrance is a small opening, two and one-half inches square, on one side. This opening is provided with an inward swinging door of sheet zinc swung from the top. The door and the top of the cage are connected by a strong rubber band, so that the door, when free, is held open. The door is closed securely by means of narrow strips of stout paper stuck, with sealing-wax, to the door and the lower edge of the box. Admission to the box can only be had by removing the obstructing papers.¹ This might be effected in several ways, by scratching, biting, or pulling the paper off, or even by butting the door in with the nose. It was expected, however, that biting or gnawing would be resorted to in most cases, as this would be the easiest method.

Series I. Rats I and II. Previous to the experimentation recorded in Series I of Group I a few tentative tests had been made with Box II upon a pair of rats; one of which was *Rat I or II* of the later experiments. The results of this experimentation were so unsatisfactory that the method was abandoned temporarily.² This was eighteen days before the beginning of this series. A brief résumé of these abortive experiments and suggestions as to the reason of their failure is given in the foot note below.³ They have a positive value in showing how im-

¹ This box was also described in the *Am. Jour. of Psy.*, Vol. X, 1899, p. 426.

² *Am. Jour. of Psy.*, *loc. cit.*

³ For several days before the experiments were begun, Box II had been left in the cage with the rats. The door was left open so that the rats might become fully acquainted with the apparatus, thus eliminating the element of unfamiliarity. The first experiment was tried at 9 A. M. After nine minutes of running about and climbing over the box, one of the rats suddenly seized the paper and tore it loose (one strip only was used). The noise of the door springing open frightened the rats

portant it is to conform to the character of the animal studied. This previous experience of one of the rats in this series possibly accounts for the apparent superiority of the rats used in this series over those used in Series II of this group.

Experiment 1. After the usual reconnoissance the rats pawed away the small amount of sawdust that chanced to be around the bottom of the box; then pulled off one of the strips of paper. The other strip, being attached loosely, permitted the door to swing inward about half an inch. The rats attempted to squeeze their heads in, and thus forced the door open. Time, 10 m.

Experiment 2. Got the door open in 14 m. They appeared to give up after working a few minutes, but soon returned with renewed vigor.

Experiment 3. The rats have located the obstacle, and confine their operations to the immediate vicinity of the metal door—pushing it with nose, *clawing* at the papers—not gnawing—and occasionally digging away the sawdust. Finally *clawed* the paper off. Time, 3 m.

Experiment 4. *Clawed* the paper off. Time, 2 m.

Experiment 5. They spent much time digging the sawdust away from the front of the door. They seem not to have learned

away, but after a short hesitation they entered and secured the food. Time, 10 m. Experiment 2 was made 25 m. later. (The food was taken away—only a crumb being allowed as a “reward of merit.”) After 20 m. of investigation the rats gave up the task and lay down in their nest. The box was removed. Experiment 3 was tried at 3.50 P. M. the same day. The spring was thrown after 45 m.; but this was accomplished by casually butting the head against the door. For 12 m. after the door was open their timidity prevented them from entering the box. They then snatched the food and ran out as if in great terror. On the following day four more experiments were made. The time was reduced to 3 m. in three experiments. The place was located, but the paper was not identified as the obstructing object. After experiments 4, 5 and 6, the food was taken away. In the 7th experiment the rat that had done all the work before seemed stolid and refused to work. The other rat accomplished nothing. The former died the same day. This apparatus was then given up, and Box I was tried.

These experiments were not a total failure, though the number was insufficient for the attainment of definite results. But their value would have been vitiated even if the rat had lived and they could have been carried further, for the method was very crudely applied. (a) The most opportune time for experimentation with rats is their time of greatest activity—late in the afternoon. They normally sleep all day. Their activity in the morning was purely factitious, due to extreme hunger. (b) The quick succession of experiments, followed in each case by deprivation of the fruits of their labor, was bad method. Nothing could be worse pedagogically, at least from a human standpoint. To establish an association train of which the motive and first term is hunger, and the end and last term is satisfaction of hunger, the train ought to be fully realized each time. The success of the later experiments, under the same conditions, established the validity of these corrections.

yet that the strips of paper are the real obstacles. They claw at the papers in a haphazard way—a sort of general scramble about the door. Nothing definite is yet expressed in their movements. Time, 3 m.

Experiment 6. Tore open the door, using both teeth and claws, in 1½ m.

Experiment 7. Tore open the door in 2 m. A few minutes later one of the rats went carefully sniffing around the outside of the box. She then entered and examined the inside, sniffing and pawing curiously. After coming out she dug the sawdust from under the edge of the box near the door. These actions illustrate the rat's method of getting thoroughly acquainted with his surroundings. The prominence of the olfactory and the motor elements are striking. The digging suggests that this box is not yet discriminated from Box I.

Experiment 8. The rats ran around and over the box a few times, and then dug a few strokes in front of the door. Then one of the rats, seizing one of the paper strips firmly in her jaws, tore away the upper half. Ran away as if frightened by her success. Soon returned and tore off the *other half*. She then seized the other piece and jerked that off. Entered immediately, got food, and came out to eat. It was a definite, business-like proceeding. Time, 3 m.

Experiment 9. Time, 1 m. Ran once around the box; then stopped in front of the door and dug away the sawdust. *Clawed* at the paper, using the teeth only as accessory. It is pretty clear that they use their teeth only as a last resort. N. B. They had not eaten last night's supper, yet they worked just as though they were hungry. This suggests at once the complexity of the problem we are dealing with. The action of the rats in this case is probably an outcrop of the primitive hoarding or property instinct. This is exceedingly strong in rats. An admirable illustration of the point is furnished by a female rat, with young, who made twenty-five journeys from and to her cage, carrying food;¹ and, in general, both male and female show a well-marked tendency to provide against a rainy day. Incidentally this is eloquent testimony to the persistence of "wild traits in tame animals,"² for these rats are practically strangers

¹ This was a rat whose litter of young was under observation. As she was quite tame her cage was often left open, so that she could roam over the table upon which stood several cages. On one occasion several small piles of dog-bread (small pieces) had been left about the table. Soon after coming out of the cage she discovered one of the piles, and proceeded to carry all of the bread to her cage. Then she continued her quest, and did not stop till she had secured every pile, making twenty-five journeys. This, in the face of the fact that she was always well-fed and had food in her cage at the time.

² Cf. Dr. Louis Robinson's book, *Wild Traits in Tame Animals*. London, 1897.

to hunger. The puzzling side of the matter comes into relief when we remember that oftentimes the rats, when not hungry, are quite indifferent to the presence of the box containing the food. These vacillations of conduct are explicable only upon the basis of radical fluctuations in the organic tone of the animal, something akin to the fluctuations in the human organism, as, *e. g.*, when the normal acquisitive impulse is inhibited by the feeling of indolent ease.

Experiment 10. One rat did all the work. The other entered immediately after the first one was out. The successful rat dug away the sawdust from before the door, and took hold of one of the papers which projected slightly below the bottom edge of the box. This act throws light upon the remarkable persistence of the useless digging movements. The projecting papers are brought into view by the digging away of the sawdust, and are bitten at quite naturally. The digging seems useful to the rat. The second piece she quickly tore off, seizing it firmly in her jaws about midway. Time, 30 sec.¹

Experiment 11. Rat I ran once around the box, paused in front of the door and dug two strokes; then tore off the strips of paper in quick succession, seizing each strip firmly in the middle. No clawing or useless biting at the papers. The rapidly perfecting definiteness of this reaction is apparent by reference to the remark in experiment 9, apropos of the use of the teeth. Time, 30 sec.

Experiment 12. Rat II ran once around the box, dug away the sawdust from the door, and then poked the door open with her nose. Rat I remained in the nest. Three methods of opening the door have now been employed successfully: clawing, biting, and butting with the nose. Biting, as the most rapid and effective, seems to have been adopted finally by Rat I. Time, 30 sec.

Experiment 13. Rat I, after two strokes of digging, tore off the papers with her teeth. Time, 15 sec. In the course of these thirteen experiments Rat I has definitely located the obstruction (this was clear at the eleventh trial), and has eliminated all the useless preliminary movements except a mere vestige of digging. The time is reduced from 10 m. to 30 sec.

Experiment 16. Time, 20 sec. Rat I was evidently very hungry—so hungry as to fall into the error of digging violently. She stopped suddenly after a few seconds and made a savage attack on the papers. The action suggested that the hunger feeling was so strong as to start off automatically the digging reflex, which was inhibited suddenly by the memory

¹It was at this point that these two rats were first marked, for the same reason as III and IV. They are designated I and II hereafter.

of the right action. The occasion of the resurgence of this memory may have been either the sight of the door and papers, or the rising of the impulse to bite the papers, this action having followed the digging each time in the process of getting the food. Under stress of hunger, attention was directed away from means to the end. Consequently, instead of a minimizing of useless movements, there was freedom accorded to the automatic movements.¹

Series II. Rats III and IV. This series followed immediately Series II of Group I. The rats had had no experience with this apparatus. This series, therefore, is more typical of the rat's attitude toward this task (Box II) than is Series I. Reference to Table II will show this numerically.

Experiment 1. No results at the end of 30 m. The rats clearly recognized a different apparatus. They did not dig at the accustomed place, but ran around and over the box sniffing curiously. The movements were deliberate and seemed impelled as much by curiosity as by hunger. Occasionally they sniffed at the food which lay against the back side of the box—away from the door; and made one or two desultory strokes in the sawdust at that point, but showed little interest. They also nosed the papers a few times but made no attempt to bite or claw them or to butt the door. At no time did they dig in front of the door. The absence of this movement is striking, in view of its chronic persistence with Rats I and II. The box was removed at the end of half an hour. The rats were not fed.

The two interesting features of this experiment are the recognition of a different box and the non-persistence of the digging habit. One cannot but ask whether the digging impulse in this case is inhibited by the recognition of a different task—a recognition which was not at all apparent in the case of Rats I and II.

Experiment 2. Rats very hungry. At the end of 45 m. they had made no progress. Once or twice they sniffed at the door—the contrast between the solid metal of the door and the wire mesh of the rest of the box doubtless exciting attention—but showed clearly that they had no suspicion of its use. They dug all the sawdust away from the back corner where the food was, and spent most of the time savagely biting and pulling at the meshes. At the end of 45 m. the food was moved over near the door. The rats continued to bite stupidly at the wires. Box

¹The next experiment gave striking confirmation of this view. Rat I was so hungry as to try to get at the box before I removed my hand. In her excitement she gave way to several of the useless preliminary movements that had been sloughed off. Time, 35 sec. In experiment 18 she appeared less excited, discarded nearly all the useless movements, and did the work in 10 sec. Similarly in experiment 19.

was removed at the end of one hour. It is possible that their extreme stupidity may have been due to hunger—they had had nothing but a little milk for 48 hours—as is suggested in the case of the recrudescence of useless movements in experiment 16 of Series I. Curiosity, which might lead them ordinarily to attack the papers, is choked by hunger, so that they blindly follow their noses, attacking the wires nearest the food. There was also a noticeable heightening of suggestibility, each rat feverishly doing what the other did—as if afraid the other would gain some advantage.

Experiments 3 and 4. In the third experiment the rats made no progress in 30 m. (No food had been given them except a little milk.) The box was left in the cage. During the night they removed one of the paper strips, but did not attack the other. The inference seems clear that the rats did not see the point. They would have gnawed papers from the broad side of the cage just as readily. The box was removed the next morning. A fourth trial was made in the afternoon—at the usual hour. At the end of 30 m. they had accomplished nothing and appeared to be utterly discouraged. I rubbed a drop of milk on one of the papers, thinking that it might suggest the appropriate action; but they merely lapped the milk off, and did not bite the paper at all. The box was again left in the cage. During the night they succeeded in solving the problem. They had gnawed the paper off neatly, leaving but a bit at the top of the door.

Throughout these four experiments, the persistence and the stupidity of the rats were equally surprising. Stupidity is not quite an exact term, for the rats in confining their efforts, as they did generally, to the vicinity of the food, were simply acting according to their usual habit of gnawing to food by the shortest way. The fact that they finally attacked the door implies that they came to have some kind of an idea of the box as a whole being the obstruction, for the food was somewhat removed from the door. The act would seem to involve a low order of judgment.

Experiment 5. Time, 3 m. Ran a few times around and over the box, but constantly came back to the door. It was apparent that the door suggested pleasant associations. Rat III then dug a little sawdust from before the door; ran away; returned and dug some more. She then paused, sniffed at the paper meditatively; suddenly bit one strip off very neatly. Startled by her success, she skipped away; but soon returned, sniffed the second strip, and quickly tore that off. She recoiled some inches at the springing of the door, but soon entered. This was the cleanest piece of work performed by any rat up to this time. The rat seemed to have the elements of the asso-

ciation chain well in mind. The co-ordination of the elements, however, was not immediate, as the hesitation at critical points shows. A stronger concentration of attention was shown here than was shown by Rats I and II at any time in Series I. The rapid integration of the association elements suggests either a higher degree of intelligence or a more powerful affective impression consequent upon the previous success after several days of failure and hunger.¹

Experiment 7. Rat IV threw the spring by butting her nose against the door. Purely accidental; the papers adhering too loosely. The rat was surprised. Time, 1 m.

Experiment 8. The papers were cut in $4\frac{1}{2}$ m. The rats seemed to know the obstruction but "put off" attacking it. The next experiment gave similar results. Time, 5 m. They walked leisurely around and over the box as if saying: "We can get in when we want to." The work was clean and sure when they got ready to do it.

Experiments 10-12. Experiment 10. The rats promptly attacked the task and quickly performed it. Rat III. No false movements. Time, 15 sec. Experiment 11 showed striking variations. Rat III went to work at once. She approached and sniffed at the door three times before touching the papers. Finally she poked the door with her nose; then braced her fore-paw against it and pulled the paper with her teeth. As it did not yield she ran away. Soon returned and got off one strip. Then she dug in a casual way at the corner near the bread. Finally came back and pulled off the other strip. Time, 1 m. She did not seem at all sure of her procedure. On the following day, she finished the task in 50 sec. Her movements were leisurely but as definite as could be desired; not a false movement was made.

The results of this group of experiments confirm those of the first group. (a) There is the same lack of initiative on the part of two of the rats. In both series of both groups one of the rats, by superior intelligence or activity, first solved the problem; afterwards these rats continued each day to open the door, the other rats complacently falling into the habit of entering the box, after the door had been opened, and getting the food, or of stealing the food from their successful companion. There was in the case of these inactive or unintelligent rats a manifest decrease of interest and effort in getting the box open between the first and the last experiment. On several occasions they did not leave the nest till their companions had opened the door. It is to be observed, also, that it was Rat III that did all the work in Series II of Group I. As Rats I and II were not marked

¹The following day the time was reduced to 2 m.

in their series under Group I, one cannot be absolutely certain that Rat I did all the work; but the results of their series in Group II, and of the experiments with Rats III and IV in both groups leave little room for doubt. (b) The fluctuations in the time factor again come into prominence. Both series in this group exhibit these irregularities; but they appear more markedly in the second. In this series the required time falls from several hours to 1 minute, rises to 5 minutes, and falls again to 15 seconds within a period of 7 days. (c) The importance of the first success is also emphasized again in the second series of this group. This was evidenced not less by the definiteness of movement in the fifth experiment than by the decrease in time.

Some new points are brought out in this group. (a) The persistence of useless motor habits is striking. This was remarked in passing. The persistence of the digging habit was especially noticeable. This appeared prominently when the rats were unusually hungry or excited. Individual variations are apparent again in this respect; the tendency to dig is decidedly less marked in Series II than in Series I. The persistency of these motor habits is explainable by the supposition that the movements are touched off automatically: *e. g.*, the digging, by the sight of the box, the rat not yet discriminating the boxes. The action illustrates the thoroughly automatic character of motor memory. (b) The form the association takes seems largely fortuitous. The method the rat finally follows depends upon what action is accidentally successful the first time. If a rat happens to succeed by several methods, as, *e. g.*, biting, clawing, butting, there is a strongly marked tendency to select the most expeditious and effective method. This apparent selection, however, is rather a matter of inertia than of prevision. In general, it is safe to say the animal chances to hit upon the easiest method. (c) It can hardly be doubted that the affective tone of the animal organism conditions the associative processes. Slight variations in organic tone may throw the whole associative formation out of gear. This fact makes the estimation of the mental elements and values involved a difficult matter. Only proximate explanations are to be expected.

GROUP III. This group of experiments immediately followed Group II. The object was to test the rat's power of discrimination. The question arose, of course, in connection with Group II, in which a second apparatus, very like the first in appearance, was used. Both series seemed to indicate that the rats recognized a different apparatus, though the demonstration was clearer in the second than in the first series. In the first case the recognition of the new did not make sufficient impression to inhibit the almost automatic return to the old

method of entering the box by digging; but in the second series that method was not employed. But this experiment showed nothing of the real character of the discriminative process. In order to test more fully its character—its quickness and keenness, its permanence, and, if possible, its elementary character, this third group of experiments was made. Incidentally light is also thrown upon recognition and memory. In this third group the two boxes were used alternately, at unequal intervals, with the two pairs of rats. As the rats were now acquainted with both boxes, the quickness, certainty and appropriateness of reaction in the presence of each box would serve as a rough measure of the discrimination, allowance being made for fluctuations of interest under varying affective conditions. Twenty-five tests were made with each pair of rats, a summary of which follows. The order of alternation and the time results are given in Table III.

Series I. Rats I and II. This series was made immediately after a second trial with Box I.¹ They had not seen Box II for 12 days.

Experiment 1. Box II. Time, 1 m. Rat I was eager and hardly waited for the apparatus to be put into the cage. She sniffed at the door, climbed upon the box, came back to the door, dug a few strokes, poked the door with her nose in a tentative manner; finally she seized the papers (getting hold of both pieces) and tore them off. The actions were methodical and deliberate. The discrimination was not immediate, but seemed definite when arrived at. In the second experiment Rat I bit off one paper and then butted the door in with her nose. Time, 30 sec.

Experiment 3. Box I. Time, 1½ m. Rat I played around and over the box more than a minute. Finally, she went and smelled of the food which lay against the back side of the box; then came to the right spot and dug in. The action was perfectly definite *when she got ready to do it.*

Experiment 4. Box II. Time, 1⅓ m. Rat I spent half a minute climbing over the box. She then came to the door, pulled off one paper, and then tried to poke open the door with her nose. Failing in this, she dug all the sawdust away from the front of the box; then ran away; came back and pulled off the second paper. The movements in this experiment indicate that the rat is still in the "trial and error" stage. One would infer that she neither discriminates the boxes, nor knows what action is most efficacious after she has discovered

¹ These experiments gave no results other than imperfect recognition of Box I, after the series with Box II. The average time was longer than in Series I of Group I after the first.

which box she is dealing with. The contrast is marked between her recognition of Box I in experiment 3 and her confusion in this experiment. The repetition, too, of the procedure employed successfully in experiment 2 is worthy of note, especially as its failure in this case was followed by a lapse into complete incertitude as indicated by the digging. The three succeeding experiments with the same box gave practically the same result, confirming the judgment expressed above.

Experiment 7 (same box), shows some improvement. Time, 50 sec. Rat I dug completely under the box; then changed tactics and bit off the two strips of paper in rapid succession. Between the two acts there was a slight pause, the rat giving one the impression of thoughtfully considering and concluding: "I dig under and don't find the entrance; therefore, I'll bite these papers." If the reader will divest this process of its conceptual character and endow it only with the character of a conflict or succession of motor impulses conserved as memory and rising spontaneously at the sight of the box, he probably will not be far from right. The pause may be interpreted as the interval between the recognition of the failure of the first effort and the rising of the second and appropriate memory-image.

Experiment 8. Box I. Time, 30 sec. The movements were clean and rapid. It is not clear to me whether Rat I really *recognizes* this box or whether she digs automatically at the sight of any box, and so accidentally gives the appearance of recognizing. The facts noted in the preceding paragraph lend color to this interpretation. On the other hand, there seems to be more sureness and confidence in her attacks upon this box, a fact which looks toward actual recognition.

Experiments 9 to 14 inclusive were with Box II again. In the 9th and 10th the rats were either indisposed or not hungry. They were indifferent to the box, which was removed after 5 m. In experiment 11, Rat I ran slowly around and over the box, languidly dug the sawdust from before the door, and finally pulled off the papers by grasping them below the lower edge of the bottom of the box—a stupid and laborious performance. Time, 1 m. 10 sec. In experiment 13, after "fooling" for nearly a minute, Rat I did the work with expedition and certainty. Her actions suggested a small boy looking for an easy method of doing a thing.

Experiment 15. Box I. Time, 10 sec. Rat I. No false movements. Experiments 16 and 17 gave results similar in definitiveness and precision.

The final eight experiments, 18 to 25 inclusive, were made with Box II. These show the same fluctuations as noted in all preceding experiments, both in this group and other groups.

In experiment 18, Rat I, after "fooling" for nearly 40 sec., did the actual work in about 5 sec. In experiment 19, she succeeded in butting the door open with her nose. The next day she performed the task—biting off the papers—with few false movements, but it was by no means apparent that she realized that the paper was the obstructing factor. At the end of the series the matter was still in doubt, for in the last experiment, the door was butted open.

The fact most clearly demonstrated was that Rat II was utterly ignorant of the whole matter. She made no attempts in the latter part of the series to open the box, apparently quite content to share the benefits after Rat I had done the work, and doing nothing on those days when Rat I was out of humor.

The question raised under experiment 7 as to recognition of the boxes, by Rat I, receives a little light from the subsequent experiments. Absolute certainty is still lacking, but the rapidity, definiteness and precision of her movements in experiment 15, leave little doubt that she instantly recognized Box I. Her actions and manner had all the marks of the *feeling of security*, in contrast with the hesitation and indefiniteness manifested in the presence of Box II. This cannot be attributed to accidental correctness of automatic movements in the former case, for the appearance of security was observable from the moment she approached Box I; whereas her manner was doubtful and hesitating when she approached Box II. My conclusion is that she fully recognized Box I, but that the recognition of Box II was imperfect.

A similar conclusion is compelled in regard to the appropriate actions in each case. Rat I manifestly associated digging in a particular spot with the recognition of Box I. On the contrary, she never definitely associated biting the strips of paper with the appearance of Box II. In connection with biting, she continued to dig, as if supposing that work a necessary part of the process; and, throughout the series, never ceased to butt the door, though this method proved successful only three times, whereas biting was successful in thirteen cases in this series; in the series of experiments with this box under Group II, after the first five experiments, in which cases the door was sprung during a melee of scratching, biting and butting, thirteen cases of biting and only one of butting were recorded as successful. Indeed in the latter part of that series, the clawing and butting movements were almost entirely eliminated. The conclusion seems to be that under the uncertainty experienced in regard to Box II there was a recrudescence of the previously sloughed-off butting movement; and the series was not prolonged sufficiently to effect the re-elimination of this factor.

Series II. Rats III and IV. Followed Series II of Group II.

Experiment 1. Box I. Time, $1\frac{1}{2}$ m. Rat III went at once to the right place, dug a little, in a doubtful manner, with one paw; then climbed upon the box. Rat IV went to the right place and sniffed, but did not dig. Rat III soon returned, dug tentatively till she could poke her nose under the bottom, and then dug with confident haste. The appearance of the rat before that was one of uncertainty and hesitancy. As soon as this clear space was found the recognition became complete. On the second day the movements were less doubtful.

Experiment 3. Box II. Time, 30 sec. Rat III worked quickly and accurately, with no hesitation, barring a little preliminary sniffing.

Experiment 4. Box I. Time, 50 sec. Rat III dug tentatively part way, then climbed upon the box. Returned and dug in. Lacked complete assurance. The following two days gave little difference in results, but in experiment 7 Rat III went instantly to the right spot and dug in confidently. Recognition was precise and immediate, and the appropriate movements were definitely associated.

Experiment 8. Box II. Time, 5 sec. The quickest and cleanest work I have seen. Rat III came around the corner of the box, sniffed the paper once, then seized and tore off both at once. (This, of course, was accidental.) The rapidity and precision of this action leaves no doubt that the box was recognized instantly. The integration of the association between the perception of the box and the appropriate movements was complete.

The six succeeding experiments were with Box I, and show striking uniformity, experiment 9 being performed in 25 sec.; the following 5 in 10 sec. each. Recognition and association here is perfect, no false movements being made.

Experiment 15. Box II. Time, $1\frac{1}{2}$ m. At the end of $\frac{1}{2}$ m. Rat I bit one strip partly off. The strip stuck, and she ran away as if not certain of her ground. After "fooling" a minute she finished the work. (No digging movements.) The rats seem bound to "fool." The next two days the work was quick and clean, 15 and 10 sec., respectively.

The last eight experiments in the following order of alternation: Box I, three experiments; Box II, one; Box I, one; Box II, three; showed that discrimination of the boxes was practically perfect. In experiment 23 Rat III was not hungry, for she gave up the task after making one or two feeble bites at the papers. She recognized the task clearly enough, but lacked the motive to push her efforts to conclusions. Rat IV made no effort to get in; and, indeed, she was a silent partner throughout, as was Rat II in Series I of this group. She merely

took her share of food after the task of securing it had been performed by her companion.

Comparison of this series with Series I brings out some rather striking facts, however. Rat I never perfectly recognized Box II, though she did recognize Box I. On the other hand Rat III, almost from the beginning, showed perfect recognition and discrimination of these boxes. As a correlative of this fact it was remarked that Rat I did not succeed in eliminating all useless movements in connection with Box II; and in selecting, for sole use, the patently most effective method of opening the box. Both of these things Rat III quickly did. This merely emphasizes the variability in the degree of intelligence in individuals of the same variety, a fact of importance in animal as well as in human psychology, which practically, if not theoretically, is too often overlooked. The evident differences in this case cannot be accounted for by fortuitous circumstances, by accidental variations in the manner of starting the associations. There is no external reason why the digging habit should have been retained by Rat I and dropped by Rat III, when dealing with Box II. Nor is the case any better with the persistence of the butting habit. References to my diary shows that Rat III, in the course of Series II, Group II, succeeded once in butting the door open, just as did Rat I in her series; and it shows also that during the latter part of their respective series in Group II both these rats nearly eliminated the butting movement. Its reappearance with Rat I in Group III clearly indicates confusion of images on her part; and this confusion marks her as inferior to Rat III in the power to form and retain a definite useful association and to discriminate two closely similar objects—two very essential factors in the complexus of intelligence.

GROUP IV. *Rats III and IV.* Complication of the problem with Box II. After Rat III had become perfectly familiar with Box II, as related in the description of Group III, the problem was varied and complicated by removing the spring from the door; so that when the papers were removed—bitten or clawed off—the door would remain in position instead of flying open. In order to get the food, the rat, after removing the papers, had to poke the door inward with her nose and crawl under far enough to reach the food. Several interesting and suggestive facts came out in the course of these experiments. These are noted in the following paragraphs. The actions of the rats in the first experiment of this group are best described by the notes taken at the time.

Rat III was apparently greatly surprised that the door did not open after she had removed the papers. She drew back and looked fixedly at the door; she then poked it gently with her nose, but was frightened by the swinging and did not try

to enter. She had pulled off the papers dexterously, dropping them whole in front of the door. These she now picked up and carried into a corner, according to the rat's prudent custom of turning them to account for nest-building. She then came back and poked the door again; then dug all about the front and sides of the box. So she went on for some five minutes, alternately poking the door, and running about and digging. Finally she plucked up courage to poke the door open and enter far enough to get a piece of bread. Rat IV now tried to steal the food, and for several minutes there was a struggle for the prize. The honest rat lost, of course; after which she went back boldly and got the second piece of bread.

There are three interesting observations in the preceding paragraph: the stopping to carry away the papers; the surprise and perplexity manifested when the expected did not happen; and the apparent feeling of the rat that she had done the right thing, as indicated by her constant returning to the door; her digging was only desultory, but her attacks upon the door were pointed and meaningful. All these points bear upon the question of associative formations.

It often happens that the bye-products of a process are hardly less valuable than the chief product. So in this experiment, the accidental manifestation of the working of the rat's mind is of considerable value in determining the *modus operandi* of the associative process. It is certainly significant that a hungry rat stops her quest of food in order to pick up and carry away to a corner some bits of paper. The meaning of this seems to be that the nest-building instinct is so strong, that the mere sight of a bit of available material serves to distract the unstable attention of the rat from her quest of food—hungry as she may be—and turns it to the other function. (I have noticed that the rats always gather up these papers, though they generally eat their suppers first. On several occasions, however, I have seen them carry away the pieces as they took them off, before getting the food; and once, I saw this done by a young female not yet pubescent. The males, too, have the nest-building instinct and do not fail to make a comfortable nest of any available material.) If one were to speculate upon the form of the associative process involved, it might be figured somewhat as follows: The sight of the paper excites the nest-building impulse (the nature of which is not analyzable; the motor element is undoubtedly large, though one could hardly speak of it as a motor image), with its proper affective coloring. This state acts as a starting point for a true motor-image—the impulse to seize and carry away the paper, which impulse or *thought* eventuates in the appropriate action. Whether or not this be a correct transcription of the procedure in the rat's mind,

the incident aptly illustrates the manner in which their associations are formed. Looked at in one way the associations are fortuitous, depending for their form upon external circumstances; but in another and more important sense they are more or less free, depending upon inner conditions. In any given case, the associative process is grafted upon some powerful organic tendency.

The further fact that the rat returned to the original problem immediately after disposing of the papers, suggests a question of some delicacy: How did her mind revert to that problem? The most obvious explanation would be that the sight of the box revived the interrupted association process. The suddenness and directness of the return, however, suggest that the reinstitution of that chain was due to central causes. The start was made before looking at the box. The most probable explanation seems to be the resurgence of the hunger feeling, and with it the half formed associative series, though there is no proof that some other elementary factor of the series was not the connecting link.

If we return now to the conduct of the rat towards the box, after her first surprise, we find another chance for interesting speculation upon the character and form of the associative process. The train already formed may be figured somewhat as follows: feeling of hunger, sight of box, smell of food (these two probably simultaneous), curiosity, location of food in box by smell (and sight), tearing off paper, getting food, pleasurable state. In some instances, as has been noted in considering the preceding groups, the first term of this hypothetical series drops out, and the mere sight of the box is sufficient to start off the train. (It is quite possible that the instinctive acquisitiveness furnishes the organic basis for the series in such cases. It is highly improbable that any excitation of a purely sensational character would furnish the motive force.) The connection of these links becomes so intimate that when the rat is normally hungry the appropriate movements are gone through with immediately upon seeing the box introduced into the cage. Now, when this associative process is broken up at the biting-off-paper point, as in this experiment, by the unexpected failure of the door to open, what happens in the rat's mind? The manifest purpose of the animal is to get inside the box, and this desire to get inside is coupled with the idea of getting in through the door. The modified form of the association train may now be: hunger, a mixed image, motor and visual, of entering the box through the door, getting the food, pleasure. That is, one of the terms of the chain is variable—the association is not determinate. When this term is expunged, another term, perhaps a suppressed one, rises to take

its place. Of course it is not necessary to postulate such a process as the following in the rat's mind: "Biting off paper fails of its usual result, therefore I'll try another method." The only necessary elements are: the persistence of the feeling of hunger, the location of the food inside the box, either as a present smell-sensation or as memory of getting the food inside the box, or both, and the memory of getting in at that place. This last accounts for the constant return to, and the poking of, the door. The rat is at first timid and suspicious of the door, but, as she is not hurt by it, her boldness increases; and this being further stimulated by the smell of the food, finally impels her to force open the door.

The pausing of the rat when the door unexpectedly failed to open might seem to imply reflection; but this is not so in any strict usage of the term reflection. Surprise and disappointment would be quite sufficient to restrain activity for the time; and these affections would preclude the possibility of reflection, unless reflection is used merely in a descriptive sense to designate the transition from this passive state to an active state under the resurging impulse of hunger. That the rat *feels* "why" or "what" is certain, that she thinks "why" or "what" is both doubtful and unnecessary.

If the preceding analysis is approximately correct, it is apparent that the primary determinant of this associative process is the feeling of hunger. But the process is not rigidly fixed. All the terms are variable, even the fundamental term of hunger, for it was shown that, after the problem had been solved, the rats when not hungry would perform the task under the impulse of the hoarding instinct. The carrying of the papers to a safe corner—completely breaking off the box-association—was in obedience to the command of the nest building instinct, the psychical motor accompaniment of the anticipatory maternal feeling.

The succeeding experiments of this group, like those of the preceding groups, showed the ability to profit quickly by experience. Fear of the swinging door gradually disappeared, but did not fade out entirely until the ninth day. Table IV gives the time results of the series. This table shows that fear of the door was not the sole factor in determining the quickness of performing the task. It was, however, the most constant factor, and largely conditioned the first ten experiments. As in all the other experiments the relative hunger of the rats and their instability of attention were influential. The increase in the required time in experiment 5 was due to a different cause. The position of the box relative to the cage was slightly changed, turned one quarter around. This change seemed to disconcert the rat; she went first to the usual place *relative to the cage*. Sev-

eral times she passed around to the door and smelled of the papers, returning each time to the old position, before finally biting off the papers. The sudden increase in time in experiment 11, presents quite a different case. Rat III got the bread as far as the door in 45 sec., but it stuck under the door. Thus baffled, she left the bread and went around the box as if to see what was the matter. She apparently tried once to push the door back with her paw while pulling at the bread with her teeth, but was unsuccessful. This movement was probably not an intentional attempt to push the door open. The explanation rather is that the rat was trying to brace herself and placed her foot against the door for that purpose. Careful observation on this point for several days showed no tendency on the part of the rat to push back the door with her paw, while pulling the bread from under the door with her mouth. In every case of success in getting the bread, the success was due to some accidentally favoring circumstance or to an unusually vigorous pull. The fact that this exceptionally bright rat did not hit upon this obvious mechanical relation, emphasizes the casual nature of the origin of most of the rat's associative processes. It is also clear, I think, that, what properly may be called ideas, find slight place in the associative process. Cross images—visual, olfactory, motor—organic conditions, and instinctive activities are assuredly the main elements. That these elements may bleach out and attenuate into ideas is not impossible. Analogy with human experience would indeed point to that conclusion.

The permanence of the association was demonstrated in the case of this rat by setting her to the problem again after a lapse of forty days. During this time she had not seen the box, but had been fed daily with dog-bread and milk placed freely in her cage. As she had given birth to and partly reared a family of young—her first litter—it would seem that her experience had been sufficiently varied and distracting to have obliterated the memory of the experience with the box. She showed, however, perfect recognition and discrimination, biting the papers off and pushing the door open within 25 seconds.

GROUP V. Character of the Associative Process and Individual Differences in Intelligence. In the preceding experiments two points had forced themselves upon my attention: (a) that the rats severally learned the task set them by doing it themselves; (b) that they manifested considerable individual variations in intelligence. It was to test further these observations that this group of experiments was made. Especially it was desired to note individual differences in intelligence; and, if possible, indicate some of the elements of difference. That differences of intelligence obtain among the lower animals as much

as in man, relative to the range and quality of psychic activity, is, *à priori*, to be expected. General observations, and the experiments already related, had demonstrated this in regard to the rat, but further examination of the matter was not undesirable.

For this group of experiments Box II was used. Four males, eight weeks old, brothers, designated *A, B, C and D* were the subjects. These rats were kept in a large wire cage, in which was a common squirrel revolver for exercise. They had been reared carefully, and were in perfect health and spirits. From birth they had been handled and petted, so that they were as perfectly fearless as rats ever become. To all external appearance they were as alike as so many peas.

The method was exactly as in other tests with Box II. At feeding time the box with the food inside was put into the cage. In all of the experiments the rats were minutely observed, and the relative ease and quickness, with which they severally built up the definite associative process involved in mastering the problem, were noted carefully. A special effort was made to detect traces of imitation. In a gross way the relative intelligence of the individual rats would be indicated, even if little or nothing were demonstrated as to the elementary character of the intelligence. The time factor is given in Table V. As in the other cases its significance is very general, both in regard to relative intelligence and to familiarity with the problem. It is suggested, however, that the time factor is much more regular in the latter respect with these *more highly domesticated* rats than with the others. They were subject much less to distraction of attention. The following extracts from my journal give the course and the points of main interest of the experiments.

Experiment 1. All four rats ran about in the usual way,—sniffing, digging, climbing over the box, etc. They also gnawed casually at the paper. At the end of three-quarters of an hour they had gnawed off one piece and bitten at the other, but they had made no concentrated effort. They were very “flighty”—running about the box, over their cage, and in and over the revolver.¹ Several times they all sat down in solemn conclave and washed themselves vigorously. At the end of $1\frac{1}{4}$ hours they succeeded in getting in. Rat *A* was the successful one. The rats are all suggestible—when one digs at any particular place, they all dig there. The same is true in a less degree in regard to clawing the paper.

Experiment 2. Rat A. Time, $1\frac{1}{2}$ m. All ran around ex-

¹ These rats had been kept in this cage about three weeks, and had developed a great fondness for the revolver. They had made their nest in it, and always carried their food into it, whether they ate the food immediately or stored it against a time of need.

citedly for a moment, then *A* attacked the paper. He bit one piece in two, then carefully tore off both the upper and the lower half, as if under the impression that they still held the door. He then bit through the second piece. The work was done quickly, systematically and persistently, though the other rats got in his way and hindered him. They gave him no assistance, however. He knew what he wanted; they did not.

Experiment 3. Rat A. Time, 1 m. Very direct and business-like performance. The other rats crowded in his way, but he pushed them aside and took off the papers in quick succession. (Did not stop for the pieces this time.) He entered immediately, seized a piece of bread, came out, ran quickly and furtively around the cage, and hastily climbed into the revolver to enjoy in peace the fruit of his labors. One could not fail to note his manifest desire to conceal his "find."

Experiment 4. Rat A. Time, 25 sec. None of the other rats made a bite at the papers, though they swarmed in *A*'s way and into the box as soon as he got it open. Three of the rats were in the box at once. They came out almost simultaneously, and hastily scrambled into the revolver with their prizes; the fourth one was late in getting into the box, but he came out and tore wildly around the cage—like the wicked when no man pursueth—seeking a place of concealment, though the other rats were busily engaged in the revolver. The absorbing intensity of the desire to "keep," blinding him to the complete absence of all enemies, is one of the striking evidences of persistence of "wild traits" that have been of fundamental importance to the life of his race. A few moments later *A* lost his piece of bread in the litter of the nest, and came back to the box again,—as if remembering his previous *modus operandi*. A nice question arises: whether a real memory image was the determining factor in this action, or whether the coming out was merely impulsive and the apparent purposiveness, due to the sudden sight of the box after leaving the revolver. The latter explanation commends itself as the simpler, but the rapidity and bee-line directness of the action suggests the former.

Experiment 5. Rat A. Time, 20 sec. *A* ran once around the box before biting off the papers. One of the other rats followed him closely all the time and entered the box almost simultaneously with him.

Experiment 6. Rat A. Time, 20 sec. None of the other rats made any attempt to bite the papers. Experiments 7, 8, and 9 were practically repetitions of 6.

A was removed at the end of experiment 9.

Experiment 10. Rat B. Time, 2½ m. There was a considerable interval between the removal of the first and second

papers. All the rats seemed to associate the door with the desired end.

Experiment 11. Rat B. Time, 1 m. *Experiment 12. Rat B.* Time, 20 sec.

Rat *B.* was removed at this point.

Experiment 13. Rat C. Time, $2\frac{1}{2}$ m. Rat *C* paused several times at the door before making a trial. Finally he bit off one piece. This seemed to give him confidence and he quickly tore off the other piece. *D* made no attempt.

Experiment 14. Rat C. Time, $3\frac{1}{2}$ m. *C* bit off one piece at the end of $1\frac{1}{2}$ m. He seemed surprised that the door did not open. He nosed around and gnawed a little at the woodwork of the box, but made no serious attack upon the second paper until 2 m. later. He was distracted by hearing rats eating in an adjoining cage. *D* made no attempt to bite the paper, though he was close beside *C* when he pulled off the first paper—their noses were almost touching.

Experiment 15. Rat C. Time, 2 m. The rat made three determined bites at the papers before getting one off. He ran all around and over the box after each trial. *D* followed closely. After *C* had pulled one piece half off, *D* caught the suggestion and pulled at the hanging paper. Then they played with the piece they had removed for about a minute, chasing each other like kittens. Imitation?

Experiment 16. Rat C. Time, $1\frac{3}{4}$ m. *C* removed the first paper in $\frac{1}{2}$ m.; then played a minute before removing the other one. The rats were not hungry, for they had several small bits of bread stored away in the revolver. Their performance of the task without the incitement of hunger can hardly be accounted for except upon the basis of a hoarding instinct almost as imperative as hunger.

No further tests were made with *C* and *D*.

Rats *A* and *B* were tested again after the lapse of five days. Memory was perfect. Both rats attacked the papers, *B* getting off his piece first; *A*, the other piece immediately after. Twenty-seven days later this test of memory was repeated under circumstances so different as to warrant the expectation that there would be some hesitation; on the contrary the rat—it happened to be *A*—instantly attacked and tore off the papers—so definite and permanent was the association.¹ Time, 10 sec.

The results of these experiments in general served to confirm the observations and conclusions previously made in regard to the origin and the nature of the associative processes. The permanence of the association was confirmed and the impor-

¹The conditions will be given in detail in connection with another experiment to be described in a later paper.

tance of the motor element in the memory was emphasized. There were several suggestions of imitation. These will be estimated in connection with the following group which deals particularly with imitation.

These experiments confirmed also the observations upon individual differences in intelligence. It is certain that some rats show more initiative and learn the tasks more quickly and easily than others. If we eliminate the elements of accidental first success and of distractions, the fact is not impaired. Interpreted more rigorously all the tables point that way. If we take the term intelligence in its obvious biological significance as the adaptive function of the organism by virtue of which definite useful associations (habits) are formed, then the demonstration of differences is clear. Upon what particular element of the intelligence-complex the particular variations depend can only be guessed at. There are, however, some noticeable facts in the results. (a) The most striking fact observed was the apparent superiority of these young rats over the adults used in the other experiments. Comparison of Table V with Tables II and III shows the superiority of these young rats over all the adults that were tested. Rat IV, *e. g.*, had experience of this apparatus for weeks in company with Rats III and II respectively, but did not learn the task in all that time; and Rat III, the brightest of the adults tested, presents a poor record in comparison with that of Rat A. (A reduced the time to 1 m. in experiment 3, and thereafter did the work in 30 sec. or less; while Rat III reached the 1 m. mark only in experiment 7, and varied thereafter for several days from 15 sec. to $4\frac{1}{2}$ m. It is to be observed, also, that A succeeded in the first trial; III did not succeed until the fourth.) A detailed comparison would show a similar superiority of these young rats throughout. (b) A second fact of interest is that these rats were males. I am not prepared to contend that the male rats are more intelligent than the females, but this points that way. The young females used in connection with Group VI (*q. v.*) showed no more intelligence than the adults, while the adult male used in Group VI displayed more initiative than female IV. The comparison is not conclusive, however, for the young females in question were younger than the young males. The explanation may be in the greater activity and vitality of the males whereby their chances of hitting upon the right action are increased, while at the same time they are endowed with greater initiative. Superior vitality and activity doubtless is also one of the advantages of youth. (c) Another point worthy of notice is that these rats had become about as tame as possible. I am inclined to think that their almost complete freedom from fear was a very important factor in their superior intelligence.

The other rats were all more or less wild when I received them. The modification in character of these four was somewhat striking. It is not improbable that some information in regard to psychic variations may be had from studies of successive generations of animals under varying controlled conditions. The advantage of such studies is obvious, both for individual and genetic psychology.

The differences between particular individuals exist only within very narrow limits. They are almost solely in regard to the quickness and ease with which the associations are integrated and retained. Rat I, for instance, was inferior to Rat III in both respects, and, as pointed out before, Rat *A* was markedly superior to Rat III. The differences between the four young males were slight, but appreciable. No variation in method of performing the task appeared among them, though slight variations were noted among some of the adult rats.

In the way of explanation of the differences nothing more can be said than that they depend upon a complex body of interacting traits,—functional, muscular, perceptual, affective and other—correlated with corresponding physical characters. In a word it is a matter of organization. The means for analyzing further the difference between any two given cases are not at hand. As between *A* and *C*, for instance, it is impossible to say whether the difference lies in the neuro-muscular system, or in the organ of association, or elsewhere. It can only be shown that appreciable and definable differences do exist.

GROUP VI. Imitation. In this group an attempt was made to throw further light upon the matter of imitation. Many of the preceding experiments gave no evidence of imitation of any kind, others indicated a low form, about equal to motor suggestion, and in the last group there were some cases that seemed to imply a higher form. Being convinced that Rats II and IV had not profited by their companionship with the successful Rats I and III, I removed them from their respective cages and placed them together in another cage. They were tested then with Box II. The belief that they had not solved the problem, either by doing it themselves or by seeing it done, was confirmed. In spite of the fact that they had seen their successful companions perform the task not less than twenty times, they showed no acquaintance with the proper procedure. Table VI gives the numerical results. The conditions were exactly as in the preceding experiments. In experiment 1 of this group, Box II, containing food, was placed in their cage 24 hours after their last meal. The rats ran around and over the box, pawing, digging, sniffing, and occasionally biting at the wire mesh of the sides; but they showed no sign of recognition of the proper means of entrance, no more than if they had never seen the box before. At the

end of half an hour I removed the box without feeding the rats. The experiment was repeated at the same time the following day, with the result that Rat II got into the box in 2 m. She accomplished this not by biting or clawing the paper, but by butting the door with her nose (the papers adhered rather weakly). The movements of both rats were vigorous in proportion to their hunger. They wasted no time. They seemed, moreover, to locate the door as the point of attack, but without any definite method in their movements against it. The butting appeared to be accidental. In the third experiment the papers were fastened securely. Both rats clawed, bit and butted. I was unable to see which one was successful, but the fact that it was Rat II the day before and the succeeding days, leaves little doubt on the point. The association did not become *solid* in her case until the seventh day. Before that time her movements were somewhat aimless—running around and over the box and digging away the sawdust. The movements on the seventh, eighth and ninth days were so definite as to leave no doubt that she recognized the situation immediately. The marked increase in time of the three succeeding days was due to other causes than unfamiliarity—accidental distractions and variation in degree of hunger.

There was, in this case, an interesting variation of the *modus operandi* in getting the door open. Apparently the successful "butting" of the second day made a lasting impression, for the rat persisted in this mode of attack, resorting to biting only as a secondary means; and several times she succeeded in butting the door open after biting off the first paper.

As in all the preceding experiments, the inveterate "fooling" tendency was manifest. Rat II frequently would run several times around the box, pausing each time at the door, before making a real attack. This indecision appeared at times to be mere playfulness; at other times the rat seemed to be looking for an easier method of entrance, for she performed the task definitely enough when she got ready. Another possibility is that it was merely stupidity, the proper action not being suggested at first. The association was inhibited in some way. Whatever may be the explanation, this characteristic renders impossible the representation of the gradual perfection of the associative process by a uniform time curve, and complicates the analysis of the process.

After Experiment 12, Rat II was removed and a fresh rat, a male, Z, was put with Rat IV. They manifested equal ignorance of the process of getting into the box, the new one actually making the first purposive attack upon the door. He succeeded in pushing it open, the paper adhering loosely. On the second day, the door was more carefully secured. Neither

had succeeded at the end of ten minutes, so the box was removed.

After Rat IV was separated from Rat III, a half grown female was put with Rat III. The use of Box II was continued. The results of these experiments also weigh against imitation as an agency in the process of learning the task. In nine trials, this rat gave no evidence of imitating Rat III in getting into the box. Five experiments with another rat of the same age gave similar results. In the latter case the young rat learned the task quickly, but this was due to the fact that she happened to be hungry and eager two or three days when Rat III was inactive.

My conclusion from all this experimental work, and from much other observation of rats is that they do imitate, but that imitation with them is relatively simple. They imitate simple actions; but I have seen no case of what may, in lack of a better term, be called inferential imitation. By this I mean merely: learning to do a thing by seeing another do it—the purposive association of another's action with a desired end. For example, not one of the eight rats that might have learned to open the door of Box II by seeing another rat do it, ever thus profited by such experience. Each rat learned the task for himself, and learned it by doing it. On the other hand imitation of simple actions is of frequent occurrence. Very often if one rat begins digging, all are eager to dig in the same place; if one runs over the box, over the box they all go. This kind of imitation is exhibited in some simple experiments with the common squirrel revolver previously mentioned.¹ This was kept in a large cage containing several rats. In numerous tests by this method it was observed that almost invariably when one rat climbed into the cylinder others would follow. Such is also the form of imitation noted in the diary of the young white rats, where the young one imitated the action of the mother in pulling at a piece of excelsior.² This simple form of imitation depending upon the immediate functional connection between sensory and motor centers in a lower level—like the frown of a three months' baby when the nurse frowns—covers all the cases of imitative action I have observed in the course of these experiments. The fact that Rat *B* took so much less time than Rat *A* in learning to open Box II might be interpreted as evidence

¹ Cf. *Amer. Jour. Psy.*, Vol. X, No. 3, p. 425. "After the rats have learned to run the revolver a test of imitation may be made by introducing uninitiated rats into the cage. The difference in the time required to learn the lesson may be taken as a rough measure of imitation."

² Small: Notes on the Psychic Development of the Young White Rat, *Amer. Jour. Psy.*, Vol. XI, No. 1, pp. 87, 100.

that *B* had profited by *A*'s experience, and, consequently, as evidence of the higher imitation. The assumption is unnecessary. *B* had profited by *A*'s experience to the extent of associating the getting-into-the-box with the locality of the door, thereby eliminating the many useless movements around and over the box that a perfectly "green" rat would have made. The recognition of the door as the point of attack is probably due to his having entered there rather than to his having seen *A* strip off the papers.

Logically, however, this lower form of imitation might explain a more difficult case than the preceding. Suppose that one rat is led by immediate suggestion to imitate the simple action of another in gnawing the paper: *i. e.*, while one is at work, the other comes along and without any idea of the end begins to gnaw also—just as the young one referred to pulled the excelsior. The paper gives way and they both go in. The association is now started between gnawing at this particular place and getting the food, and may be perfected later. The imitative factor consists solely in the impulsive imitation of a simple action.

Wide as are the explanatory possibilities of this lower form of imitation, it is difficult to demonstrate that higher forms do not exist. In dealing experimentally with this matter there is one highly important factor that cannot be controlled completely, *i. e.*, attention. Distractions may be minimized almost to the vanishing point, but that point cannot be reached with such a psychically unstable compound as the rat mind. Even if external distraction were entirely eliminated, there would still be the insuperable obstacle of subjective conditions. And the conditions are distinctly unfavorable for demonstrating the higher imitation. The attention of the rat is focussed, under the compelling feeling of hunger, upon getting at the food. The call is for individual action. Attention is turned away from the actions of his companion. It is not impossible that a form of imitation, involving the higher associative processes, might be demonstrated if it were possible to direct the attention of the rat to the actions of the other rat, while retaining undiminished the affective basis for action. Any attempt, however, to restrain or constrain the animal would defeat the desired end—attention would assuredly be diverted from the objective point to the restraining conditions—would be lost in the affective absorption induced by them. An illustrative case is an experiment recorded by Dr. Thorndike¹ in his experiments with cats. In this case the experimenter tried to instruct his cats to perform certain acts by holding the paw and guiding its

¹Animal Intelligence (*Psychological Review*, Monograph Supplement, No. 8, June, 1898), page 70.

movements successfully. "I took the right paw and, putting it against the lower or right-hand side of the button, pressed it round to a horizontal position." Three cats were tried, but none learned to do the act this way, although the lesson was repeated several times. This method manifestly disregards the factor of attention above adverted to, and consequently fails to demonstrate the absence in animals of those higher associative processes involved in inferential imitation.

The matter is still open, though my own observations upon the rat predispose me to regard the explanation in lower terms as probably correct in the case of that animal. It would seem that the rat is probably incapable of attending in such a way as to bring the relation of perceived means and end into focus; and consequently incapable of higher imitation.

It cannot be assumed, however, that this presumptive conclusion, even if it were more certain, can be stretched to include the imitative processes of all other animals below the primates. (There is hardly any doubt in regard to the primates.) The mental divergences among species, and even among varieties, are so great as to preclude any crass generalizing. However strong one may feel the *à priori* assumption to be, definite conclusions must wait upon more abundant concrete evidence and the fuller returns of comparative neurology.

TABLE I.			TABLE II.			TABLE III.				
SERIES I.		SERIES 2.	SERIES I.		SERIES 2.	SERIES I.			SERIES 2.	
Exp.	Time. ¹	Time.	Exp.	Time. ¹	Time.	Exp.	Box.	Time. ¹	Box.	Time.
1	90 —	35 —	1	10 —	Failure.	1	II	I —	I	1:30
2	8 —	2:30	2	14 —	"	2	II	— 30	I	— 30
3	2:30	2 —	3	3 —	"	3	I	1:30	II	— 30
4	3	1 —	4	2 —	Indefinite.	4	II	1:20	I	— 50
5	3:30	1:30	5	3 —		5	II	— 50	I	1 —
6	2:30	— 30	6	1:30		6	II	—	I	1:30
7	1 —	1.30	7	1:30		7	II	— 50	I	— 25
8	5 —	— 30	8	3 —	4:30	8	I	— 30	II	— 05
9	1:30	—	9	1 —	5 —	9	II	—	I	— 25
10	1:45	— 10	10	— 30	— 15	10	II	—	I	— 10
11	1:30	— 15	11	— 30	1 —	11	II	1:10	I	— 10
12	— 30	— 10	12	— 30	— 50	12	II	— 30	I	— 10
13	— 45	— 10	13	— 15		13	II	1 —	I	— 10
14		— 18	14	— 35		14	II	— 30	I	— 10
15		— 15	15	— 10		15	II	— 10	II	1:30
16		— 30	16	— 20		16	I	— 20	II	— 15
17		— 40	17	— 35		17	I	— 20	II	— 10
18		—	18	— 10		18	II	— 45	I	— 15
19		— 20	19	— 20		19	II	— 25	I	— 10
						20	II	— 25	I	— 10
						21	II	1 —	II	— 15
						22	II	—	I	— 15
						23	II	— 35	II	—
						24	II	—	II	— 30
						25	II	1 —	II	— 30

¹ The time is in minutes and seconds in all the tables. The long dash in the time column indicates that the box was removed after 5-10 minutes.

TABLE IV.		TABLE V.			TABLE VI.		
Exp.	Time.	Exp.	Rat.	Time.	Exp.	Rat.	Time.
1	5:30	1	A	75 —	1		— ¹
2	3 —	2	A	1:30	2	II	2 —
3	3 —	3	A	1 —	3	II	3 —
4	2:30	4	A	— 25	4	II	3 —
5	5 —	5	A	— 20	5	II	3 —
6	—	6	A	— 20	6	II	2 —
7	3 —	7	A	— 20	7	II	— 30
8	1 —	8	A	— 30	8	II	— 30
9	— 50	9	A	— 30	9	II	— 20
10	— 10	10	B	2:30	10	II	1:15
11	2 —	11	B	1 —	11	II	— 50
12	— 20	12	B	— 20	12	II	1 — ²
13	—	13	C	2:30	13	Z	1 —
14	— 20	14	C	3:30	14	—	—
15	—	15	C	2 —	15	IV	5:30
16	— 55	16	C	1:45	16	Z	2:30
		17	A&B	— 10			

¹ Removed at end of ½ h.; neither got in.

² Interval of 4 d. between 11 and 12.