EXPERIMENTAL STUDY OF THE MENTAL PROCESSES OF THE RAT. II.

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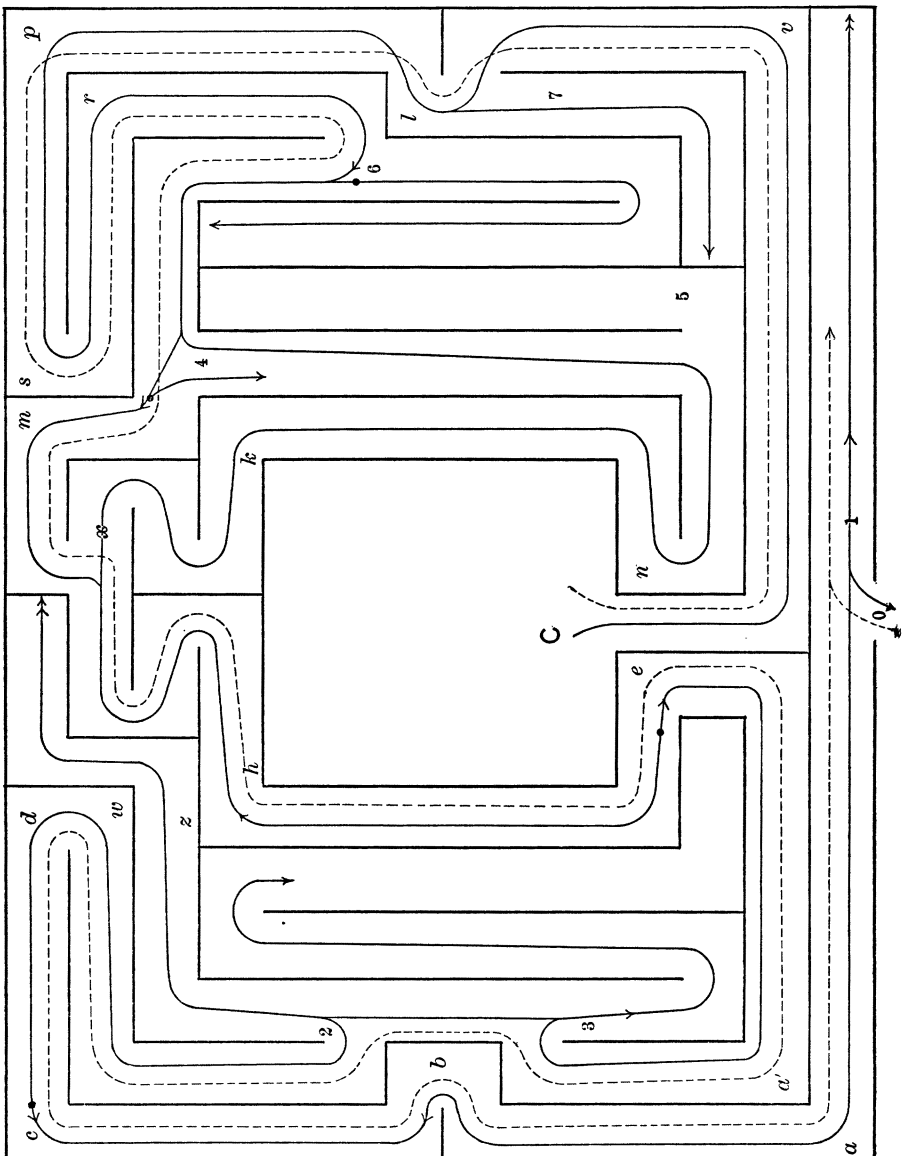
The present paper, which supplements, in a measure, two former papers, (*Am. Jour. Psy.* Vol. XI, Nos. 1, 2), presents in detail the results of some further experimental studies upon the mental life of the rat. Primarily a study in method, an attempt to observe this animal under approximately experimental conditions, the methods and devices have worked well enough to warrant considerable confidence in the results, and the inferences therefrom. The paper describes the apparatus used and the conditions of experiment, gives a detailed account of a typical series of experiments, compares the intelligence of wild rats and the tame white rats (same variety) upon the basis of these experiments, discusses briefly the general form or character of animal intelligence, and makes some suggestions in regard to the mental facts involved in solving the problems set in the tests. It is not in any sense a systematic rat-psychology.

APPARATUS AND CONDITIONS OF EXPERIMENTS.

The aim in these experiments, as indicated above, was to make observations upon the free expression of the animal's mental processes, under as definitely controlled conditions as possible; and, at the same time, to minimize the inhibitive influence of restraint, confinement and unfamiliar or unnatural circumstances. Fear, which in lack of a better term, may be used to include the three influences just noted, and too great difficulties are the things most rigorously to be guarded against. On the positive side, the experiments must conform to the psycho-biological character of an animal if sane results are to be obtained. This is not the same thing as guarding against "too great difficulties." The difficulty of two tasks, judged by their complexity and the quality of intelligence necessary for their performance, may be identical; yet the problem involved in the one may be so different from that in the other, so remote from the animal's racial experience and life habits as to be absolutely outside his capabilities. A human being has to know how the elements of an action feel—or better, has to know the *feeling* of the elements—in order to perform the action. The

importance of these characteristic differences is obvious enough where structural differences provide the basis: no one would



expect a buffalo and a rabbit to do the same things in the same way. No less important, though less easy to define and designate, are the specifically psychic traits of an animal which constitute its character, and which depend in the main upon its biological conditions. The cat and the rat are not antithetical in structure, nor do they differ very widely in degree and kind of intelligence; but their life habits, both on the emotional and the intellectual side, present an effective contrast. The cat, primarily a hunter, is bold, independent, and aggressively open; the rat, on the contrary, primarily the hunted, and only secondarily a hunter, is timid and furtive. His timidity is comparable to an intellectual obsession. His boldness when displayed is impudent and half apologetic, never self-contained and unconscious like that of the cat. I daily see this matter exemplified in the case of a pet rat and a young cat. Though the rat has compelled the cat to respect his rights, the characteristic difference of mental attitude is not greatly changed.[1]

Conforming with such considerations, appeal was made to the rat's propensity for winding passages. A recent magazine article upon the Kangaroo Rat, by Mr. Ernest Seton Thompson[2] illustrates well the radical character of this rodent trait. Mr. Thompson gives a diagram of the Kangaroo Rat's home-burrow, the outline of which bears a striking resemblance to that of the apparatus used in these experiments. It suggests that the experiments were couched in a familiar language. Not only do they conform to the sensori-motor experience of the animals, but they also fall in with their constructive instinct relative to home building.

The Hampton Court Maze[3] served as model for the apparatus. The diagram given in the Encyclopedia Britannica was corrected to a rectangular form, as being easier of construction. The character of the problem was not affected. Three mazes were made. The first was as follows. The dimensions were 6 by 8 feet. The bottom was of wood, the boards being fastened together so as to make a portable whole of the apparatus. All the rest: top, sides, and partitions between galleries were of wire netting, ¼ in. mesh. The height of the sides was 4 inches; the width of galleries, the same. In the center was a large open space. The accompanying diagram gives the ground plan of the maze. The entrance is marked by the figure *O*. Figures *1* to *7* indicate seven blind alleys—seven

[1] The character of the white rat is modified somewhat by its immemorial life of captivity, but less than might be supposed. All the primitive traits emerge under the appropriate conditions.

[2] Scribner's Magazine, April, 1900.

[3] *Cf.* Ency. Brit. Art. "Labyrinth."

possibilities of error. It will be observed that *4* does not lead necessarily into the *cul-de-sac 5*, but does inevitably furnish a chance for error. The letter *x* marks a dividing of the ways either of which, however, may be followed without completely losing the trail. Certain other points are indicated by letters *a*, *b*, *c*, etc., for convenience in description. C stands for center. A glance at the maze will be sufficient to convince one of the difficulty of the problem. This maze is designated as Maze I. The two other mazes were identical with this, except that they were made throughout of wire netting, bottom as well as top and sides. The apparatus could thus be reversed and a mirror reproduction of the original form could be obtained. In use they were fastened temporarily to wooden floors. These mazes will be spoken of as II and III. In all cases the mazes were placed upon tables 2½ feet above the floor. The floor of the maze was covered with sawdust. This was renewed whenever a new rat was introduced.

To obviate the affective disturbance which would have resulted from change of conditions just prior to experiment, as little difference as possible between the conditions of experiment and of ordinary experience was allowed. The event frequently justified the precaution. The rats were kept in an ordinary observation cage,[1] a well ventilated and commodious apartment, standing flush with the maze at *O*. Back of the cage, upon the same table, was a screen completely concealing the observer during experimentation, but permitting him to look down upon the maze and mark every movement of the rats. When ready for experimenting, the sliding glass door which closed the passage into the maze was lifted by means of a pulley connection running over the screen. This door always opened with slight noise and friction. Food was placed in the central enclosure. To obtain this, the rats had to find their way through the tangled maze. They were kept hungry enough so that they would set about the task vigorously. Experimenting was done in the evening to minimize the influence of distracting noises.

In spite of these precautions there was, as might be expected, some lack of uniformity in the results—so much has to be allowed to the internal conditions and to individual variation.

As a beginning, two series of experiments were made; one with wild brown rats, *mus decumanus;* the other with white rats, albinos of the same variety. The original purpose was to use the wild rats exclusively; but the difficulties were considerable, and the white rats were found to serve the purposes of experiment quite as well in every way. In all the experiments after the first series white rats were used. The most of the later

[1] *Cf. Am. Jour. Psy.*, X, 3, p. 135.

experiments were made to determine special points, and will be described in their immediate connections.

As before stated, the rats were let into the maze at the time of experiment and were left until the following morning. The entire night was theirs for investigating the maze. This method excludes the possibility of a quantitative study, and intentionally, for reasons given within.

DESCRIPTION OF EXPERIMENT.

In presenting the results of these experiments I give a detailed account of a typical series, following this with explanatory suggestions. The conduct of the rat is described as it was minutely recorded at the time of observation. This is supplemented in passing by comparison with other experiments and by details taken from them. This plan of presentation has the advantage of exhibiting in detail the method of animal intelligence in actual operation,—it is analogous with vital staining in histology—rather than in figuring its general form as could be done by the method of graphic representation in curves. Again, in view of the rôle one's own prepossessions and limitations are bound to play in interpretation, it will be an advantage for the reader to know the observed facts upon which the writer's interpretations are based. I readily concede that my facts may be found more valuable than my inferences. Be that as it may, all who are interested in comparative psychology will agree that careful and impartial description of the objective facts of animal intelligence is a desideratum.

I have selected for detailed description my second series of experiments. The subjects were two young male white rats, about 3½ months old. They were perfectly tame—pets from birth.[1] Nine experiments were made at intervals of two days; and a tenth after a lapse of three weeks. The conditions were the same as with the wild rats of the first series.

Before giving this detailed description I wish to present a brief summary of the observations upon the wild rats in series 1, in order to make clear the passing comparison, given within, between the wild and the tame rats. This comparison is purely a by-product of the study—it was not contemplated at all in the beginning—and it takes us a little out of the straight line of exposition; but the results have a suggestive value sufficient to warrant the delay.

The subjects of Series I were three adult wild rats—a male and two females. They had been in captivity about three months, but were in perfect physical condition. No particular

[1] Rats A and B of Group V, reported in *Amer. Jour. Psy.*, Vol. XI, No. 2, pp. 156 ff.

effort had been made to tame them except by excluding as far as possible occasion of fright. They remained so wild, however, as to necessitate the extreme precautions described above.

The first two experiments failed of definite results because of imperfect conditions. The rats were frightened by external disturbances, so that they failed to move (Exp. 1,) for more than 10 m., and did not reach C in two hours. This they accomplished during the night in each case. It was not until Exp. 3 that the conditions were made to conform perfectly to the description above. After that, observation was made and results recorded more satisfactorily. The influence of the first two trials is apparent in Exp. 3, the journey being made in 15 m., and with 8 errors.[1]

In this experiment and in all succeeding experiments of the series the male showed striking superiority to the females. In this case they did not reach C until 15 m. after the male — indeed they did not leave the cage till after he had reached C and was well on his way back to the cage. He met one of the females at *c*. Under the same stress of hunger, they exhibited throughout the series very much less boldness and initiative. This humbler character comes out again in the deference the females showed the male. Whenever he was monopolizing the food they would make furtive attemps to steal the prize, or approach with deprecating squeaks as if begging to be allowed to share. On several occasions I saw him chastise a female severely for trying to get the food away. The females, too, were less apt in familiarizing themselves with the maze. In the fifth experiment, I observed that they showed little familiarity or assurance, and seemed much more disconcerted than the male when they got into a blind alley. The male died after Exp. 7, but even after that the improvement of the females was relatively slow. Four more experiments showed slight gain. Their timidity seemed to abate but little, and prevented them from giving full attention to the problem.

Later tests with male and female white rats gave the same general result, though the difference was not so marked. In only one case out of ten or twelve pairs observed did the female show equal initiative. The significance of this is not, I think, that the intelligence of the males is higher or more refined, but, rather, that it is more effectual by reason of being less subject to affective disturbances and inhibitions. The case is analogous with a point made later in comparing the white and the gray rats: the appearance of greater intelligence really may mean

[1] By errors I mean the returns—*e. g.*, going back from *d* to *a*—as well as the positive errors of following wrong paths.

nothing more than that one animal is somewhat more energetic than another, moves more and faster, and consequently has more chances of succeeding in a trial and error series.

It is interesting to note, also, that domestication tends to reduce this disparity between the sexes. It suggests the very live question whether civilization, which is a kind of domestication, operates similarly with the human species. Popular opinion seems to lean towards the affirmative; and we find expression of this movement of the social mind in the tendency to identify the aims, conquests, and education of the sexes. On the other hand anthropologists recognize a progressive differentiation of the sex types, physiologically and biologically. Possibly a point in development has been reached where psychological development has attained a greater freedom than heretofore from physiological and biological determinants.

But to return from this digression. The male (m) showed the influence of the previous experience not only in the reduction of time and errors, but also manifestly by avoiding several errors and by hesitation at certain points. He even returned to the cage without any mistakes. In some parts of the maze the movement had some definiteness, but generally had a groping appearance. This in itself is significant, suggesting that already he passed beyond the stage of purely accidental selection, that he had already acquired some kind of recognition, however vague, of rights and wrongs. The selection of paths begins to be purposive. In the four succeeding trials, in which this rat was a subject, there was observable a constant increase in the purposiveness of the movements. This takes the form of definiteness and speed where no error was possible, and of doubt and indecision where there was choice of path. The indecision tended to fade away, but did not disappear completely in this (too) brief series.

If the matter were illustrated graphically by curves, we should have the curve of speed and definiteness beginning with a maximum of slowness and complete indefiniteness, and sweeping down gradually to relatively perfect definiteness and a minimum of time. The curve of choice, on the contrary, would begin very low, rise gradually as the recognition of critical points became more acute, and would then fall gradually as the right association became habitual.

As further illustrative of this increasing purposiveness I note from the records the following pertinent observations. In Exp. 4, "one could not fail to see that the rat was trying to select his path—there seemed to be some kind of an image in his mind that he was trying to follow. The first time he came to 4 he hesitated, then went wrong; each succeeding time he seemed to recognize this place, for he went by confidently.

Indeed after the first time around he seemed sure of his path beyond this point, and at *s* visibly accelerated his pace each time." In Exp. 5, he made fewer errors, and recoiled more quickly from an error when made. Movements were all rapid, yet cautious. Again made "the error at *4*, and again quickened his pace as he passed it the second time. This acceleration was accompanied by a flick of the tail and a general abandon that said, 'I've struck the right trail.'" The movements in Exp. 6 "were purposive. He apparently knew when he was on the right and when on the wrong road. The right (latter) half of the maze seemed better in mind than the left; before reaching *m* the movements were cautious and uncertain—several mistakes—but beyond *m*, they were rapid and secure—no mistakes." Exp. 7 gave similar results.[1] There is little reason to doubt that a few more trials would have enabled him to learn the way perfectly as did the white rats in many later experiments.

The time and error factors of the five experiments, which were accurately recorded, were as follows:[2] III—15, 8′. IV—10, 2′. V—1¾, 4′. VI—3, 4′. VII—⅝, 3′. It will be seen that the relative decrease in time is more nearly constant than that in number of errors—*e. g.*, Exp. *4*, which required 10 m., gave only 2 errors; Exp. 7, requiring only 50 seconds, gave 3 errors. Probably the small number of errors in Exp. *4* is largely accidental. There is doubtless a somewhat constant relation between knowledge of the path (indicated by relative number of errors) and the time required to traverse it. It must be remembered, however, that organic conditions vary so as to make this relation practically indemonstrable.

In this series of experiments, the writer failed to observe any thing that would indicate that the sense of smell played an important rôle in the process of solving the problem, at least so far as following a trail is concerned. In no case could I make out that the male followed his own latest track or the females followed the track of the male, which often would have led them almost directly to the goal. All later experiments confirmed this view. The evidence is given in detail in its proper place *infra*.

It should be remarked, also, that the females gave no evidence of intelligently following the male, when by doing so they might have gone directly to C. The rats passed and repassed each other, each going his or her own way. Occasionally one would be deflected from his path to follow another, but seldom for any considerable distance. This same independence was observed

[1] Reason for discontinuance was death of the rat—disease unknown.
[2] Roman numerals indicate the experiment number; the plain Arabic, the time in minutes; the accented Arabic, the number of errors.

in all later experiments, so that I think imitation even in its simplest form[1] cuts a very insignificant figure in this matter.

One other matter of interest is the general conduct of the rats in the maze. I have spoken already of the initial timidity. The manner soon became more confident, affective tension was relaxed, and curiosity and the play instinct were unloosed. In Exp. *3*, after the rat[2] had eaten and drunk a little, he seemed to become thoroughly happy, and, for the nonce, quite oblivious of the world of traps and snares. He alternately ate, drank, and ran curiously about the maze, investigating all the passages in a sprightly and eager manner. In Exp. *4*, I note "the restless curiosity they all manifest after the first pangs of hunger are appeased, carefully exploring all the passages, feeling and sniffing along the sides and tops and into all the angles and corners. Their conduct impresses one strongly as being the expression of a free curiosity—a fundamental and irreducible desire to know all this new environment. It has not at all the appearance of a further search for food, but rather a seeking for the feeling of security and at-homeness attendant upon knowledge of surroundings.

I pass on now to describe in detail Series II, with white rats.

Exp. 1. A. 13 m. *A* came out of cage 2 m. after the door was opened. A few steps into *1*—turned and forward to *b*—back, end of *1*—into cage—end of *1*—to end of *2* without pause—into *3*, half to end—turned and forward to *4*—a few steps into *4*—turned, foward to *6*—a pause, then to end of *6*—out and back, via *4*, *n*, *k*, *x*, as far as *c*. A slight pause, then forward to end of *2* again—out, and a few steps into *3*—back and thence to *h*, pausing a moment at *e* to sniff and dig—back to *e*—forward continuously to end of *7* (very slowly by *4*, as if having some recognition of the place, sniffing cautiously from side to side of gallery)—back to *6*—thence forward to C.

Rat *B* up to this time had made little progress. *A* soon came out of C, and for 15 m. the two rats ran about the maze, most of the time in the circuit immediately around the center, *i. e.*, *z-h-x-k-n*, fagging back and forth, digging at the base of the wall and biting at the wires—the depth of stupidity, one would say. *B* reached C 15 m. later, and *A*, a second time, a minute later than *B*.

It is well briefly to notice the points of interest presented in this first experiment. (1) In regard to timidity they presented a contrast with the wild rats of the preceding series. They spent little or no time looking and listening. Their movements were free and unconstrained. (2) Their movements were a trifle less vigorous than those of the brown male. They go about the business more deliberately; their movements appear less automatic. (3) At the turns in the road, the rats frequently stopped, as if in doubt which way to go. (4) The meaning of the sudden stops and turns is not very intelligible. A rat going at a good pace through an unobstructed gallery may stop suddenly or wheel about and go in the opposite direction. This indecisiveness is a constant trait of the rat character, as had been remarked in all my preceding observations and experiments. Other than this

[1] *Amer. Jour. Psy.*, Vol. XI, No. 2, p. 162.

[2] I refer solely to the male in these illustrative examples.

flightiness or unstable attention, no explanation of these movements offers itself. I do not regard this as ultimate; but for the present, at least, it must serve, as the conditions of attention are not apparent. (5) The fortuitousness of the first success is evident. The great number of errors, the repetition of the same errors, the marching and countermarching, and the general appearance of *lostness* amounted to a demonstration of the accidental nature of this first success. (6) It appears also that the very first experience was little profited by. It was noted that *A*, in course of his first wandering journey to C, did seem vaguely to recognize the locality of *4* when he approached it the second time—his slow and cautious movements seeming to indicate that—and there was a suspicion of a similar recognition at 3; but these were the only suggestions of having 'profited by experience,' and after leaving C, *A* wandered just as blindly as *B*, when trying to return.

Most of these points will come up for consideration in the fuller discussion later on.

Exp. 2. *A*, 3 m. The two rats kept together until *a'*, having gone to the end of *1*, but having avoided *2* and *3*. *B* paused to pick up a crumb. *A*, forward without pausing, by direct path, *i. e.*, *x-m*, to end of *6*—turned instantly and went like a flash to *7*—thence more slowly to C, pausing but once (to eat a crumb) on the way. *B*, after eating his crumb, went forward slowly and carefully to end of *6*. He looked as though he were following *A's* trail by scent. Here an insane suggestion seemed to grip him (there was no external occasion for fright); he wheeled, made a wild rush, and bit up at *h*. He then ran about foolishly for 15 m, twice going again to the end of *6*. The last time, he flashed out much as *A* had done, not pausing until *r*—thence slowly, as if following a trail. At *s*, *A* and *B* met, stopped a minute to play, then each went his own way, *B* still appearing to follow the trail.

In this second experiment the noticeable things are the immense improvement shown by *A*, and the appearance of "trailing" by *B*. Three possible explanations of *A's* improvement suggest themselves: (1) the right path is selected by sense of smell; (2) by lucky accident; (3) the path is identified by other means than smell. A fourth explanation might be one that included these three as variable factors. I defer discussion of this point, merely indicating that I do not regard the first factor (smell) as important, in spite of the presupposition in its favor, and apparent following of the trail by *B*, noted above.

Exp. 3. *A*, 4 m. Distraction on part of the rat prevented a full record. The time of actual performance was not more than 1½ m. For the other 2½ m., *A's* attention was directed to a foreign matter. On the whole, however, he showed more familiarity with the path, making fewer pauses, and moving more rapidly and securely.

Exp. 4. *A*, 1¾ m. *B*, a few seconds longer. *A's* course: End of *1*—forward quickly and into *2*—stopped at last turn and back, seeming to recognize his error here—paused at *3*, then to end of that *cul de sac* —turned instantly, and ran swiftly and continuously to *4*—entered *4*, going slowly around circuit *n*, *k*, *x*—paused meditatively at *x*—then suddenly started on a quick gallop, accelerating at *m* and *4*, and not pausing till he reached C. *B* followed about the same course, but went less quickly. He showed less the appearance of "trailing." In the case of both rats, something very like disgust was manifest when they found themselves at the end of a blind alley. The instant recoil, the swift retracing of their steps, and the decisiveness with which they turned from the blind alley into the right path, seldom going *back* now beyond the entrance to the *cul de sac*, seemed to indicate something more of mental content than the mere recognition of the impossibility of get-

ting further that way. Another noticeable fact was the increased security and confidence of all their movements. The slow, blundering *modus operandi* of the first experiment had given place to rapid, definite, purposive movements. This was evident alike in respect to the right moves and in connection with the errors. It has been noted already that the errors were retraced with great rapidity. It remains to remark that in nearly all cases, the entrance into the blind alleys was marked by hesitation, and the journey to the end was made slowly and doubtfully. It was also noted in passing that *A*, after passing *x* the second time accelerated his pace, and increased the acceleration at *m* and *4*, indicating thus a greatly increased familiarity with the path from *x* on.

Exp. 5. *B*, 1 m. *A*, 1½ m. Started together. Omitted *1* for the first time. At *2*, separated, *A* entering *2*, *B* going on after a momentary pause. *B* entered *3*—proceeded only a few steps—turned confidently—out and forward to *n*. Delayed here and was overtaken by *A*.[1] Both remained here a little: *B* first recovered his wits, and suddenly dashed back through *4*, and forward to C. Less than 10 sec. from *n* to C; and went with full assurance, hesitating at no point. The appearance of the action was as if some kind of an image of the path to C had flashed in upon the creature's mind touching of simultaneously the motor discharge. At this point I do not wish to discuss the possible nature of the process involved further than to say that the term image does not mean here visual image. Representation, perhaps, would be a less objectionable term to describe this hypothetical mental correlative of the action.

In this experiment *B* for the first time equalled *A's* performance. In all the former tests, both with this apparatus and with that of preceding experiments (*Am. Jour. Psy.*, Vol. XI, No. 2, p. 156 ff.), he had shown a slight inferiority. In the succeeding experiments he was generally first to *C*, though there was slight difference.[2]

Exp. 6. *A*, 1½ m. A variation introduced. The entrance into the center, C was barred by Exp. Box II (*Loc. cit.* above) used in a former series of experiments with these rats. The door of this box, which was held closed by strips of paper pasted upon the door and the sill, was opened inward by a spring when the papers were removed. Food inside the box. The reappearance of this problem so unexpectedly and under such different circumstances after the lapse of 27 days constituted an interesting test of the permanence and distinctness of the memory.[3]

B first out. Directly to *2*, pause—a very human-like indecision. After 5 or 6 abortive starts each way, finally entered *2* and proceeded slowly to end. Turned and swiftly retraced his steps. At mouth of *2* joined by *A*. Together they proceeded placidly to end of *3*. Turned instantly and galloped back swiftly out of *3*, not slowing up until *e*. Here *B* charmed by the odor from C stopped to dig. *A*, forward soberly, hesitated at *x* turning now right, now left, but finally on to *n*.

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[1] Apropos of the possible rôle played by smell in selecting the path, it is significant that *A*, after following the path traversed by *B* from 3 to 5, *here* diverged, turning into *5* before going to *n*.

[2] Later in this same experiment I observed a striking instance of the difference between the affective character of these rats and of their wild brothers. The laboratory cat jumped upon the maze and showed a friendly interest in the rats. They were startled at first, but soon were trying to bite her toes through the meshes. Under the same circumstances, the wild rats were stiff with terror for 15 minutes.

[3] The term memory is used in this paper in its generic sense. In the present instance it implies: in the presence of accustomed conditions, a mental state leading to the performance of the task incident to the situation. It does not simply "actual and distinct recall;" much less, reference of the reproduction to a former time in the subject's experience. Nor does it imply self-consciousness. It does imply a feeling of recognition—'at-homeness.' The phrase 'permanence of association' might be used, but that this recognition-element is not properly a part of its connotation.

He delayed there a moment—then hastened on to C, via *4*, without further delay or mistake. (*B*, reached *n* before *A* left, but seemed to 'lose his head'—ran back to *e*—to *n* again—then *5*—reached C more than a minute after *A*.) When *A* came to the barricading door of the box, he attacked the paper without hesitation, almost automatically. After pulling off the first paper, he ran back a little way in the characteristic half-frightened manner of the rat, but returned immediately and removed the other paper. All accomplished in a few seconds. The memory was perfect.

This experiment illustrated also the fact of the increasingly definite recognition of critical points, as evidenced by the hesitation and indecision at those points. This was decidedly more striking than in the preceding experiments, especially in the case of *B* at the entrance of *2*, where, as stated, he exhibited a quite human hesitation, turning now one way, now another. The conduct of *A*, at *x*, was hardly less noticeable. *B's* hesitation continued all the way to the end of *2*, as indicated by his slow and doubtful progress; and his disgust when he reached the end, was as manifest as had been his indecision at the beginning.

The rats were exceedingly active during the evening, traversing curiously all the galleries of the maze, investigating every angle and nook; and returning frequently to C for a drink of milk—they had carried the bread out into the maze at once. As an illustration of the rapidity and accuracy of their movements, I saw both rats go from *n* to C without a suspicion of a pause in less than 5 seconds. The distance is approximately 16 ft. The path includes 16 right angles and 4 chances for error.[1]

Exp. 7. *B*, 3 m. Slow in starting. *B* went to end of *1*—then slowly forward as if feeling his way—eliminated errors *2* and *3*, hesitating only slightly—blundered at *x*, going to *n*. After running back and to between *n* and *k* for a moment, he passed on *via x*, *m*, etc., to C, without further hesitation or error. Tore off the papers instantly on reaching C. Memory on this point quite as perfect as *A's*. After taking a drink of milk, *B* seized a piece of bread and started back—paused at *h* to eat—met here by *A*, and hastened on to *c*—stopped again to eat. *A* followed here in a few moments, and *B* went to the cage. Almost immediately he went again to C and brought back the other piece of bread. The rats ate their supper in the cage, making frequent trips to C for milk. *B* made the journey twice very swiftly without error or delay; and both of them, several times with but one error. They take a run to C for a drink as naturally as they would turn around, or as a man would go out between the acts. The ease of it all indicates a pretty definite knowledge of the way through the maze, as well as of the hedonistic end to be attained by traversing that path.

Exp. 8. *B*, 30 sec. *B* made the journey with only one error—went half to end of *1*—and without indecision at any point. (He paused 6 or 7 seconds at one point, but because his attention was caught by something outside of the maze). Tore off the papers instantly. The total time between entering the maze and entering the box was just 30 sec. Deducting the time of the pause (above noted) and that for pulling off the papers—about 5 sec.—we find the actual time in traversing the maze less than 20 sec. This rapidity of movement illustrates—measures roughly—the almost automatic definiteness of the mental pro-

[1] The next morning, I found the rats had carefully deposited the remnants of bread and the *bits of paper* in their cage. A few days later, after I had given them abundant excelsior for a bed, they ceased to save the bits of paper from the box. The collecting impulse seems to be inhibited by the feeling *enough-at-home*.

cess—not quite automatic, as appears from the fact that the animal will again make mistakes and show indecision at critical points. The movements are habitual but not secondary automatic. Attention and discrimination are not wholly shelved. *A* was a few seconds later. Both went back to the cage with their bread without mistake. In making another trip to C a few seconds later, *A* went right to *4;* here hesitated as if "scratching his head," then entered this gallery slowly and doubtfully—only a few steps however; then with a sudden turn and a triumphant flick of his tail he returned to the correct path. This is peculiarly interestiug from the fact that he made this error complete, the first time, going completely around the circuit *4*, *n*, *k*, *x*, *m*. I watched *A* make two more journeys to C. The fourth time he did not pause or hesitate or slacken his pace at *4*. As in Exp. 7, frequent journeys were made to C for milk. These averaged one every 4 or 5 minutes during the half hour I watched. They were made generally without error and in as brief time as 15 or 20 sec.

After the edge of the appetite is worn off a little, the rats tend to let loose the play instinct in the fullest degree. In all their journeys they 'play by the way,' strolling nonchalantly into the blind alleys, now sniffing listlessly, now with half-eager curiosity in all the corners, and angles. That they *know* their way pretty well, however, is evident from the manner in which they take a sudden start from any place in the maze and 'flash' to the end—either end. To one who is familiar with the ways of the white rat, or who is able to imagine his action from the descriptions and figures above, the term 'flash' in this connection will be appreciated as realistically literal.

Exp. 9. *B*, 1 m. (Exp. Box II not used). Each rat made 2 errors: both entered *1;* *A* took long way at *x*—*i. e.*, *k*, *n*, *4*—*B* turned into *4*, went as far as *n*, then retraced his steps. It is noteworthy that these are the most persistent errors. Neither rat hesitated at *2* or *3*. It is not apparent why the error at *1* is so persistent—it was fully eliminated only once. The persistence of the errors at *x* and *4* is a simpler matter. A glance at the diagram will show that these mistakes may be rectified without a return—indeed they are not, properly speaking, mistakes at all, but rather failures to select the shorter path. In each case the rat has but to push ahead in order to recover the right trail. It is probable that these errors would be fully reduced with a sufficient number of trials—in fact other series of experiments confirm this view, though, as will be seen, they are the last errors to be sloughed off; and, with some rats, absolute certainty is not reached in a great number of trials. In one case, forty did not suffice.

The series really concludes with this experiment, the tenth serving merely to test the memory of the maze experience. It adds little or nothing to the data for explaining the formation of the associative nexus, and the mental material and powers involved in that process.

It was made 22 days after Exp. 9. The results were: *B* reached C in about two m., making errors at *1*, *2*, and *3*; *A*, a few seconds later, errors at *1*, *3* and *x*. They clearly recognized the maze, but some of the details had slipped away. *B* hesitated at both *2* and *3*, as did *A* at *3* and *x*, showing that there was recognition of these critical points, but that the memory was indistinct. After returning from *3*, *B* proceeded more securely—his gait had been slow and doubtful before—hesitating only at *x* and but a second there.

The same experiment in several other cases gave similar results—a constant tendency towards a partial lapse of the association.

Analyses of Results.

In appreciating the results of this series of experiments,

about the same facts come into view, only more distinctly, as in the case of the wild gray rats; the initial indefiniteness of movement and the fortuitousness of success; the just observable profit from the first experiences; the gradually increasing certainty of knowledge indicated by increase of speed and definiteness, and the recognition of critical points indicated by hesitation and indecision; the lack of imitation and the improbability of following by scent; the outbreak of the instincts of play and curiosity after the edge of appetite is dulled. In addition are to be noted the further observations upon the contrast between the slow and cautious entrance into, and the rapid exit from the blind alleys, after the first few trials; the appearance of disgust on reaching the end of a blind alley; the clear indication of centrally excited sensation (images) of some kind; memory (as I have used the term); the persistence of certain errors; and the almost automatic character of the movements in the later experiments. Viewed objectively, these observations all converge towards one central consideration; the continuous and rapid improvement of the rats in threading the maze, amounting to almost perfect accuracy in the last experiments. No qualification of this view was found necessary in the light of many later experiments. Rather they all confirm it. The mental aspect is considerably more complex, the mental factors, much more difficult of analysis and evaluation; but the central fact in the process seems to be the recognition by the rats of particular parts of the maze. Deferring consideration of this side of the matter, and looking now only at the objective side the important points are, as in case of the wild rats: (1) the increase in speed, and (2) the decrease in the number of errors and in uncertainty. Comparison of the two points is as follows:[1] I-13, 13′. II-3, 2′. III-4, —. IV-1¾, 4′. V-1, 2′. VI-1½, 3′. VII-3, 2′. VIII-½, 1′. IX-1, 2′. (X-2, 2′). As with the wild rats, we find a fairly constant decrease in time and in number of errors. Similarly, there are fluctuations both in time and number of errors, *e. g.*, Exp. 9 shows an increase over Exp. 8 in both respects. This is to be expected from the character of the animal and the confessed impossibility of completely controlling even the external conditions, not to mention the particular internal conditions in each case. Allowing for such variable factors, the relative time required and number of mistakes made furnish a fairly accurate index of the progressive acquaintance of the rats with the problem. The contrast between the first slow, blundering, accidental success and the definitely foreseen success of Exp. 8 (taken as the best) is striking. This is brought out even more saliently by the

[1] Significance of the numerals is the same as *supra*.

graphic representation on p. 201 than by the figures collocated above. The solid line indicates the course followed in Exp. 1; the dotted line that followed in Exp. 8.[1] The arrows mark the point where the rat stopped and turned about, and are pointed in the direction he was headed when he stopped. The dots (•) indicate points where considerable pauses were made. The arrow and dot between *q* and *m* indicate that the rat, when returning from an abortive essay into *q*, went as far as that arrow, paused, then turned and went forward.

Turning now for a brief consideration of the relative results of experiments with the two kinds of rats, some interesting and rather unexpected facts crop out. Comparison of the time and error tables of the two series discloses no considerable superiority on either side, although in this comparison I disregarded entirely the first two experiments of Series I, comparing the 5 trials recorded of Series I with the first 5 of Series II. The average of times required and errors made gives the white rats the advantage in regard to time; the brown rats, in regard to errors.[2] In view of the handicap of two experiments, it will be seen that the advantage lies with the white rats throughout. The brown rats had gained comparatively little from the first two experiments, imperfectly conditioned to be sure, but in which they had the usual freedom of the maze during the entire night. I am of the opinion that even if the conditions of experiment had been identical, the balance still would have tipped in favor of the white rats, so potent is the inhibitive influence of fear with the wild rats. The rational conclusion seems to be that there is little difference between the two in actual intelligence. The wild rat is somewhat more vigorous and active, and consequently this excess of activity increases his chances of accidentally hitting upon the right path. This might secure him a slight advantage *in time* in perfecting his knowledge of the path. It would not signify, however, any advantage in quality or degree of intelligence. It might ensure a larger number of associations (supposing a free life for both animals) but would not make any difference with their delicacy or complexity. In short, the results of superior activity are not intelligence, though they seem often not to be discriminated, in accounts of human as well as animal doings. This superior activity, however, is fully balanced by the wild rats' greater susceptibility to fear under these strange conditions.

[1] That Exp. 1 gives the record of Rat *A* and Exp. 8, of Rat *B* is inconsequential. The attainments of the two were practically equal. (The course was marked on a diagram at the time of observation.)

[2] Average time: Series I, 5 m. 19 s.; Series II, 4 m. 33 s. Average of errors: Series I, 4 1-5; Series II, 5 1-5. In Exp. 3 of Series II, I was not sure whether there were 4 or 5 errors. The maximum is taken.

In ability to profit by experience—in this case, to learn a definite route involving possibilities of frequent error—the two are not far different.

This conclusion does not tally very well with the general opinion that animals suffer mental deterioration under domestication. However that may be with other animals, it evidently is doubtful in this instance. The white rat in comparison with his wild congener is somewhat less vigorous and hardy (especially does not endure cold or hunger so well), and has sloughed off some of the timidity and suspiciousness of the wild rat; on the other hand, his senses with the exception of sight are as keen, his characteristic rat traits are as persistent, and his mental adaptability is as considerable. The *modus operandi* of the two kinds in the maze shows little variation. Likewise there is no difference in the curiosity manifested, either in kind or degree. In view of the many generations of luxurious idleness[1] of the white rat, this profound and enduring nature of specific psychic traits is striking. A pertinent illustration was furnished by a young rat that escaped from his cage and was loose about the laboratory for several days. He had just been weaned when the accident occurred. Food was rather scarce and he got pretty hungry. Finally one morning he found his way into the chicken pen, and in less than two minutes had killed two chickens, and was upon a third when discovered. The chickens were three times as large as himself. The killing was done by biting through the throat of the victim, and was as neatly and deftly executed as if the executioner were an old hand. The importance of this illustration lies in the fact, that this is exactly the method of killing employed by the wild rats. The only possible preparation in his own experience this pigmy could have had for such serious business must have been in play with his fellows. That, however, was general rather than specific; and, at best, was of slight importance, as he had reached the playing age but few days before. Another typical illustration of the persistence of specific traits is furnished by a perfectly tame pet rat that exhibited the greatest fondness for a hole in the base-board of a room where he was allowed to run, making for the hole every time he was set free in the room, and dodging in and out at every sound; yet so tame that he would come out and allow himself to be caught as often as I went to the hole and called. Such cases give some suggestion of the tenacity of those fundamental specific traits which "persist with undiminished vigor" long after the conditions of life which

[1] I cannot find that the white rat is known to exist in the wild state. There is a tradition that it was brought to the Occident from an immemorial existence in China. I am not able to verify this tradition—or disprove it.

called them into being have changed radically. In these cases non-use certainly has had but little effect in reducing the potential force of specific instincts.

What is true of such relatively superficial specific traits is doubly true of generic instinct-feelings. Curiosity is a good example, frequently coming into evidence as it does in these experiments. Its intensity is not diminished with the long domesticated white rats. Nor is it greatly changed. Ribot, rightly regards curiosity as the basis of the 'intellectual sentiment.' "This primitive craving—the craving for knowledge—under its instinctive form is called curiosity. It exists in all degrees, from the animal which touches or smells an unknown object, to the all-examining, all-embracing scrutiny of a Gœthe; it always remains identical with itself."[1] I am persuaded that Ribot is right in regarding this affection as primitive and as a primitive craving for knowledge; not merely a reaction to hunger or sex stimulus. The desire for familiar acquaintance with environment, concomitant with fear and uneasiness in strange surroundings, is about as fundamental as hunger. Observers of wild animals in their native haunts tell the same tale. The astronomer who orients himself with respect to infinite worlds satisfies the same craving for knowledge and calms the same uneasiness in strangeness as does the animal which seeks all the knowledge possible to him of his universe. The reduction of chaos to cosmos begins there.

Such considerations as these suggest the question whether zoölogical psychology may not profitably turn from its almost exclusive search for variation, to a search for the relatively invariable factors in the animal mind. In order to do this the ideals of structural psychology must be departed from somewhat, and attention directed to the study of the instinctive traits and tendencies, out of which, in higher differentiations, human nature is made. From the point of view of psychic statics these are composite and analyzable; but, from the point of view of psychic dynamics, they are themselves primitive and elementary. By this method, if by any, will be gathered the material for a natural history of mind. From this source light may be expected upon many obscure problems in individual and anthropological psychology.

General Form of Animal Intelligence.

The amount and variety of fact brought out in the preceding description and analysis must serve as excuse for this somewhat tedious presentation of details. It justifies the initial assumption that the results of such a study as this are qualitative

[1] Ribot: Psy. of Emotions. (Eng. Tr.) p. 368.

rather than quantitative; and that a generalized statement of results or any graphic representation whatever of the data by curves, would indicate only the most general form or tendency of animal intelligence, which was decidedly less what I wished to exhibit than the details of the performance. My conviction of the importance of this aspect of the case is strengthened by M. Hachet-Souplet's brilliant suggestion of a new method of classification of species from the psychological point of view.[1] M. Hachet-Souplet shows clearly that there is very good reason for cutting loose from the trammels of morphological classification in our psychological investigations of animals. If, however, such a desideratum is to be realized, it must be by studying the mentality of the different kinds of animals with the same minuteness that morphology employs in its domain.

A few words, however, as to the 'general form of animal intelligence' and a more adequate appreciation of the value and limitations of the 'curve' in connection with the same may not be *mal apropos*. In a former paper,[2] I have noted that a time curve would be an insufficient index of the definiteness and certainty of an animal's mental processes, on account of the inconstancy of internal conditions. In this paper I have pointed out that a more adequate representation might be made (at least for these experiments) by compounding the time and error curves, and also a curve representing the indecision at critical points—if such could be extracted. Such a compound curve, however, would still be far from telling the tale fully and precisely.

The one extensive and important study in comparative psychology in which the graphic method of presenting results is largely employed is that of Dr. Edward Thorndike upon cats, dogs, and chickens.[3] Dr. Thorndike's methods with his cats and dogs was to confine the hungry animals in boxes, small enough to be uncomfortable, from which they might escape by "some simple act, such as pulling at a loop of cord, pressing a lever, or stepping on a platform." Food was exhibited outside

[1] P. Hachet-Souplet: Examen psychologique des animaux, Paris, 1900. Schleicher Frères.

[2] *Am. Jour. Psy.*, Vol. XI, No. 2, p. 136.

[3] Edward Thorndike: Animal Intelligence. Psy. Rev. Monograph, Vol. II, No. 4, June, 1898. Dr. Thorndike's methods have been criticised by: W. Mills (Psy. Rev., May, 1899); C. Lloyd Morgan (Nature, July 14, 1898); and Kline (*Am. Jour. Psy.*, Vol. X, Nos. 1, 2, 3). Kline's criticisms are fragmentary, but valuable. Morgan's Review in Nature is discriminating and sympathetic. Mills raises some objections to Dr. Thordike's work, but is blinded at times to the other's meaning by his polemical ardor. Thorndike has replied to Mills (Psy. Rev., July, 1899).

the enclosure as a special incitement to vigorous effort; and escape was rewarded with the food. The time required to escape in successive experiments was recorded, and the results represented by curves. These time curves are regarded by Dr. Thorndike as exact indices of the progress of the animal in the formation of the required associations. Though these temporal data do not seem so significant to me, as to Dr. Thorndike, for the reasons given above, yet they do exhibit, I think, what I have called the general form of animal intelligence; or as Professor Morgan expresses it in an analysis of Dr. Thorndike's paper (v. note above), "they bear out the contention that the method of animal intelligence is to profit by chance experience, and depends upon the gradual establishment of direct associations." I suppose Höffding means essentially the same thing when he says: "The simple primitive consciousness does not feel the need of concepts but goes passive from disappointment to disappointment." Professor Morgan reports in the same paper, having attempted to extract from some of Mr. Thorndike's carefully plotted data, a mean curve for the method of trial and error. The attempt was not very successful he admits; but he thinks the resultant curve does indicate the gradualness of the process which theoretically would be expected. On the whole, this conclusion seems to me essentially sound. At least, my own observations with rats, under what seem to me more natural, and sympathetic conditions, give confirmatory results. I have plotted tentatively a number of time curves, both from the results of my experiments with the maze and with other devices; and they show no radical variation from the general form of Dr. Thorndike's curves. I think Morgan is right in asserting that "the form of his curves affords no particle of evidenee for reasoned behavior." No more do mine. It must be remembered that Morgan rigidly limits the term reasoning or rational procedure to the process of drawing logical inference. The relation between experiences must be perceived as such. The transitive moment between focal points in consciousness must itself be capable of becoming focal. The reasoning creature must be able to 'focus the therefore, think the why.'[1] In the broader sense of practical adaptation to varying conditions by direct association; or as Binet[2] defines it: "an organization of images determined by the properties of the images themselves, so that the images have merely to be brought together for them to become organized, and reasoning follow with the inevitable necessity of a reflex"—Morgan readily admits reasoning in animals.

[1] Morgan: Comparative Psychology. *In locis.*
[2] Psychology of Reasoning. (Eng. Tr., p. 3.)

Morgan further made a comparison of his mean trial and error curve, with a mean curve of rational procedure, which he plotted from Dr. Lindley's data compiled in his "Study of Puzzles." (*Am. Jour. Psy.*, Vol. VIII, No. 4.) These present a clear contrast, he thinks. In the latter case he finds "a sudden leap from failure to success when the trick of the puzzle was discovered and understood;" as opposed to a "gradual sweep towards rapid and assured success" with the former.

There is one fact, however, in connection with the trial and error curves that Morgan does not remark. Nearly all of Dr. Thorndike's curves show a sudden fall after the first success. My own experiments with various devices gave similar results. This fall is analogous with the fall in the curve of rational procedure after the 'trick was understood.' This fact does not affect the distinction between the two processes. The sudden fall in the trial and error curve indicates only effectiveness for reproduction of the first right association. In this method, learning the trick or the task, depends in the first instance upon performing it fortuitously so far as previsioned end is concerned; and requires then time and repetition for perfecting the knowledge. Improvement depends upon memory of previous performances, or forgetting useless details. The relation of the acts does not become focal. On the other hand, in rational procedure, the trick may be understood before it is performed. The entire plan of solution may be envisaged before a move is made. As a matter of fact, however, in the great majority of cases tested by Dr. Lindley, in which rational procedure was employed, the understanding at the beginning was only partial, the plan was vague and hazy. The understanding became full and definite through abortive attempts at practical solution. The younger children, Dr. Lindley found, as would be expected, used almost exclusively the trial and error method, chance success and direct association. With older children rational procedure based upon a considered plan came progressively into evidence. "The younger children succeed through a long series of slight variations. Occasional lapses into useless movements occur; but the trend is by a slow and primitive method of exclusion towards the goal." Among older persons the inhibitive influence of failure is stronger. The memory of the failure takes its place as a substantive element in consciousness and constrains the subject to reconsider, to deliberate. The variations, too, are wider and more far-reaching, indicating a larger and more complex grasp of attention. Yet comparatively few, even of adults, pursue a strictly rational procedure. The close similarity between animals and children is obvious.

The fact that the trial and error method plays so large a part in human mentality, and especially that it predominates with

children, still further supports the view taken in the beginning of this paper that animal intelligence works almost exclusively by this method. Although this hypothesis was assumed for the present case only, it certainly covers adequately a very large part of animal activity. Most anecdotal cases of animal reasoning are explainable upon this ground. So far as the narrowly experimental studies of animals go, they point in the same direction. As yet, however, these are too limited in number and too restricted in scope to be very conclusive.

On the other hand, however, there is yet something to be said. The analogy between children and animals is so close that the manifestation of reason in some very young children suggests that some animals may have the same power. Preyer cites the case of a two-year-old child getting a cricket and standing upon it in order to reach a desired object.[1] M. Hachet-Souplet[2] shows wide variations of psychic faculty among animals of closely related morphological groups. Individual variations, too, are indubitable. M. Hachet-Souplet has no doubt that some animals reason. His opinion is important since he is an experimenter in a large and fruitful way, and is at the same time in the main sharply critical of his facts. He describes a striking case of reasoning in a coati, as follows: "Un de nos amis nous ayant rapporté un merveilleux trait d'intelligence de la part d'un coati, nous avons résolu de provoquer artificiellement autour d'un autre coati, des circonstances analogue à celles dans lesquelles le premier s'était trouvé, quand il donna une si grande preuve de sagacité. On sait que l'espèce est très friande d'œufs de poule; nous en plaçâmes un sur une haute cheminée de façon à ce qu'l pût être vu du coati et, après avoir éloigné légèrement les sièges, nous quittâmes la pièce; en nous arrangeant toutefois de manière à ne rien perdre de ce que ferait notre sujet.

"Il s'agita d'abord, saute deux ou trois fois; mais, voyant que son élan ne le portait qu'à mi-hauteur de la tablette, il semblait réfléchir un instant. Il se dirigea ensuite vers une chaise en chêne ciré qu'il essaya d'attirer du côté de la cheminée, mais ses pattes glissait sur le bois et il renonça à son enterprise; il semblait désespéré. Cependant il aperçut dans un coin un paquet de vieux chiffon et parut frappé d'une véritable *idée. Ayant pris une des bandelettes, il en entoura le pied de la chaise et il se mit à l'attirer à reculons.* Quand le siège fut contre la cheminée, en deux bonds, mon coati monta sur celle-ci et s'empara de l'œuf." Manifestly the coati in this case perceives relations, more complicated relations, indeed, than the

[1] Preyer: Infant Mind. (Eng. Tr., p. 185.)
[2] *Loc. cit.*

relation perceived by the child cited above. Such a mental expression goes beyond the explanatory possibilities of 'direct association by trial and error methods.'

Perhaps the real question after all is not whether animals perceive relations, but, rather, *what animals perceive what kind of relations.* This would seem to be the logic of M. Hachet-Souplet's position; and, what is more important, it is the logical method of psychogenetic study. Granting that animals may perceive relations, we have, then, definite and feasible problems to investigate: the kind and complexity of the relations perceived. This method should give data for a better understanding of the nature of animal reasoning,[1] judgment, inference, and the consciousness attending these processes. It would not be surprising if degrees of complication and of symbolism were found to constitute the differentiæ.

On the whole, the modern studies of comparative psychology confirm Hume's acute observations on the nature of animal intelligence. "Animals, as well as men, learn many things from experience, and infer that the same events will always follow the same causes. By this principle they become acquainted with the more obvious properties of external objects, and gradually, from their birth, treasure up a knowledge of the nature of fire, water, earth, stones, heights, depths, etc., and of the effects which result from their operation. The ignorance and inexperience of the young are here plainly distinguishable from the cunning and sagacity of the old who have learned from long experience to avoid what hurt them, and to pursue what gave ease or pleasure. . . . An old greyhound will trust the more fatiguing part of a chase to the younger, and will place himself so as to meet the hare in her doubles; *nor are the conjectures which he forms on this occasion founded in anything but his observation and experience.* Animals, therefore, are not guided in these inferences by reasoning, neither are children, neither are the generality of mankind in their ordinary actions and conclusions, neither are the philosophers themselves. Animals undoubtedly owe a large part of their knowledge to what we call instinct. *But the experimental reasoning itself, which we possess in common with beasts is nothing but a species of instinct or mechanical power that acts in us unknown to ourselves.*" This statement of Hume's[2] as to the general form of animal intelligence has not been improved upon. His expression 'experi-

[1] Benn (Gk. Philosophers, I, p. 381,) makes the interesting suggestion that animals reason disjunctively ("after a canine fashion"). It is from the disjunctive form that all other forms of reasoning are successively evolved.

[2] Hume: An Enquiry concerning Human Understanding. Section IX, pp. 85 ff.

mental reasoning' seems to me singularly happy and accurate, guarded, as it is, by the suggestion of its subconscious character —especially happy in comparison with the clumsy expressions of some modern comparative psychologists whose abhorrence of anthropomorphism leads to the opposite extreme both in thought and expression; and causes them to inveigh against that vice *ad nauseam*. I suppose Hume would be dealt with summarily on this score by these writers. But is not a certain amount of chastened anthropomorphism a wholesome specific, a kind of saving grace against the scientific pedantry that thinks to create a new science of comparative psychology with the imperfect instruments of experiment and the law of parsimony. The law of parsimony is important, no doubt, but it may be employed too rigorously. The real difficulty lies not in the tendency to interpret animal intelligence in the terms of human experience, for we have no other way; but in the faulty and imperfect analysis of human experience. That is the real vice of Romanes' work. His analysis did not go much deeper than the discursive adult human understanding. This difficulty is intensified, not only by the fact that human consciousness is permeated, and, as it were, recreated by self-consciousness; but also by the fact, not always heeded, that the more elementary and obscure phases of human experience, as yet, have not been fully and definitely analyzed.

Another difficulty, not less real and important, but not sufficiently remarked, is found in psychophysical limitations. This difficulty is frequently met with in human psychology. Galton's Academicians who regarded mental imagery as 'moonshine' illustrate the point. They experienced no mental images; therefore, mental images did not exist. A similar limitation, Ribot thinks, leads psychologists to cavil at memory of emotions. Now, doubtless, the psychophysical disparities between man and brute are inconceivably greater than between man and man. The immensely greater rôle played by smell, for example, or motor experience, in the economy of the animal mind cannot be fully appreciated. We can hardly have any idea of the radically different tone and feeling of such consciousness; and we cannot say with any precision what modifications of intelligent processes are concealed from our view in this way.

The Process of Learning.

Whether the process of learning the way through this maze is adequately described as a gradual establishment of direct associations by profiting by chance experience depends upon the meaning attached to the phrase 'profiting by chance experience.' I wish in the remainder of this paper to attempt an analysis of the mental factors involved in the animal's solution of the

problem; and to offer some suggestions upon the character of the perfected knowledge.

It will be well to résumé the facts by following the rats *A* and *B* of Series II from their introduction to the maze, throughout their experience of getting acquainted with their new environment, to the time when they have perfect mastery of the situation. In their first trial, after a lapse of 13 minutes and after many errors, returns, and delays, they find their way into C. Here they are rewarded for their labors by all the pleasure possible to a rat from the satisfaction of a keen-edged appetite by a good meal of bread and milk. This first success is assumed to be accidental; its realization does not depend at all upon previsioning intelligence. The animal does not foresee the end and set to work to attain that end. There is no reflection. The determining conditions in the rat's mind are more immediate in their effect. The most obvious of these are: hunger, perception of the odor of the food, curiosity, normal activity (the obverse of curiosity) and the instinctive special trait of following out tortuous passages—a definite rat-hole consciousness that acts, as it were, thygmotactically. These factors, with the inhibitive balance-spring of timidity, firmly rooted and deeply toned emotionally, constitute the relatively stable background of consciousness over which play the lights of the perceptive and discriminative processes as the animal proceeds with the task. The rat, when he enters the maze, is psychically a confused complexus of these factors. No one of them looms high above the others in the wave of consciousness. Attention is dispersed; perhaps, better, distraction prevails. Nevertheless, 'experimental reasoning' begins at once. The animal keeps constantly moving; but his activity at this stage is evidently sensori-motor (or organo-motor). Motive in the sense of ideated end is absent. The nearest approach to this is the possible idea of a definite kind of food incident to the perception of the familiar food-odor. This is not impossible. On the other hand the effect on consciousness may be only an intensification of the hunger psychosis resulting in an increase of motor activity. However this may be it probably is the animal's instinctive fondness for following out devious ways his, thygmotactic rat-hole psychosis, rather than the smell of the food that gives determinateness to his movements at first. Were this trait less imperative, the rat, when he comes near the food (*e. g.*, at *e*) would become the victim of his hunger and his perception of the position of the food—for the food at this point could be located by smell—and would spend himself stupidly in endeavoring to force an entrance. In general, however, he soon passes on, going directly away from the Canaan of his desire.[1] Failure to get through by gnawing and digging,

[1] Occasionally one does just this stupid thing. Cases were noted in passing.

quickly results in a wavering and dispersion of attention. Concomitantly the perception of the odor relapses into the margin of consciousness, and the instinctive motor tendency at this juncture reasserts itself as the focal and directive influence.[1] The first success then may be set down as the accidental issue of a trial and error series, motivated by hunger and curiosity, mediated by the sense of smell and, more largely, by this instinctive motor trait, and consummated by the pleasure of hunger satisfied. And yet the term *accidental* must be used with reservations. The rats of this series, and of all others in their first trial, seemed to profit at once by experience. By this I mean that after they had made an error once or twice, though they had not yet succeeded in reaching C, they would hesitate or even avoid the error when going over the ground a second time. For example, rat *A* went only a few steps into *3* the second time he reached that place, and avoided *6* and *7* completely. A glance at the record of the first experiment will make this perfectly clear. Such cases may be attributed to pure chance; the conduct of the rat, his hesitation more than his avoidance of the error, indicates, rather, recognition and selection.

It will be remembered that the rats have the entire night each time for exploration of the maze. This results in remarkable improvement in the second trial. In the succeeding experiments the improvement is continuous in the elimination of errors and in the increase in definiteness and speed. The rats soon acquire a practically perfect knowledge of the maze, so that they can make the journey quickly and accurately when they want to do so, or stroll about as they list.

How explain this improvement? What does 'profiting by chance experience' mean in this instance? how is it assimilated and how utilized?

Doubtless one factor in the process is the memory of the pleasant experience at the end. In addition to the undirected and undifferentiated motive of hunger and the motor trait of the first trial, there is, in the second, a dimly ideated end which probably becomes progressively clearer in the subsequent experience. But the essential point is certainly the recognition of the critical points along the way and the discrimination of

[1] With several subjects the odor stimulus was done away with entirely to see whether they would make the first journey to C as well as the rats that had that stimulus. No appreciable difference was shown either in time or number of errors. The rats followed out the maze to the end, C, just as perseveringly as if the food had been there dispensing its savory solicitations. The expected did happen, however, in respect to learning the direct way to C. They made little progress in five or six trials. As there was no pleasant association at the end of the journey there was nothing to determine the building up of this definite association train.

the divergent paths at these points, leading to purposive selection of the right path. The memory of the pleasant experience at the end would be of slight avail, if the rats did not recognize the critical points and discriminate and select their paths. The animal begins by going right and wrong wholly by chance. After a few trials he comes to recognize the doubtful places, and hesitates when he comes to them, undecided which way to take. The external signs of indecision vary between standing still as if trying to think which way to go, and abortive starts each way. Sometimes to these is added standing up and sniffing in the usual manner of orientation. This movement seldom was observed after the first two or three experiments, *i. e.*, after the dilemma began to be clearly felt. At this stage, the choice of path is still about as often wrong as right. The distinguishing accidentia are acquired gradually. Progress in discrimination is marked by decrease of hesitation and in more frequent choice of the right path. The path chosen often is pursued doubtfully. If the wrong one is chosen, the error frequently is retrieved after a few steps; if it is followed to the end the return is made swiftly and the right path is taken confidently. In the final stage, errors and hesitation drop out entirely. The right path is followed from start to finish without attention to specific points *en route*.

It should be noted that the learning was slowest in connection with *o*, *x*, and *4*. The persistent confusion at *o* is attributable probably to its being at the entrance of the maze. At this point there is a maximum of affective excitement. The momentum of association has to be gathered as the animal goes along in the familiar path. In a remote way it may be likened to the stumbling and groping of an orator at the beginning of a familiar theme. The suggestion that the rats might have a penchant for right as opposed to left was found baseless by the use of the reversed maze. A definite memory of direction seems to be required. The slower discrimination at *x* and *4* was due doubtless to the fact that wrong choice at these points consisted in taking the roundabout, rather than the direct path. Strictly speaking there was no error. In all the other cases, taking one path was associated ultimately with success; taking the other, with failure—disappointment. In these cases the association would seem to be between path and distance.

In such cases profiting by experience manifestly involves the processes of recognition, discrimination and choice. If the problem set were merely the selection of one effective movement out of several haphazard movements, as was the case with the puzzle-box experiments reported by Dr. Thorndike[1] and my-

[1] *Loc. cit.*

self,[1] then the profiting by experience could be accounted for by the fading away of the useless movements. They would drop off like dead branches from a tree, of their own weight. They would be associated with nothing—either positively or negatively. The right movement would be selected *naturally*. In the present case, however, two direct associations are formed and discriminated between, and the advantageous one selected. Recognition of the critical places is equivalent to doubt as to the right path. This doubt is the correlative in consciousness of the struggle between the two associations or 'constructs.'[2] The positively useless or the less advantageous association does not fall away mechanically, but only in virtue of discrimination between the two constructs, and, finally, the conscious selection of the right one. In such a case as that of choice at x if the animal did not consciously select, there could never be any fixed association; consequently never any habitual reaction. Both ways lead to success. In a sufficient number of trials the theory of probabilities would require an equal number of selections of each path. But the short road is soon habitually selected, just as is the right path at other critical points. There is involved an elementary form of comparison and judgment; for comparison, judgment and reflection, even, are present in embryo. They all take their rise in the struggle of ideas and images, and lower down of 'constructs,' which "gives in animal, as in man, the illusion of choice and free intelligence."

Modalities of Sensation.

This section is an attempt to appreciate the rôle of the different sense-modalities in learning the task.

The conditions of the experiment were such as to exclude any very direct influence of taste and hearing. Taste gives only a pleasurably-toned experience at the end, the significance of which has been noted. The influence of hearing is limited to occasioning affective variations. Neither gives any data for solving particular difficulties.

Smell. The sense of smell might be supposed, *à priori*, to play the leading rôle, but in the present case its claims to primacy are doubtful.

In the preceding section it has been shown that the location of the food by odor, and hence the end to be reached, was an unimportant factor. In fact, it is improbable that olfactory sensation *per se* has much greater spatial significance with animals than with man. In general, animals perceive direction of odors only with the aid of air currents. The perception is quite as much tactual as olfactory.

[1] *Loc. cit.*

[2] *Cf.* Morgan: Comparative Psychology.

It is even clearer that the trail of the first accidental success was not followed subsequently by scent. In the first trial the rats invariably traversed practically all the galleries; and, after appeasing their hunger a little, carefully investigated the entire maze. It would be impossible, therefore, for them to select the right path by scenting the trail. Again, the second rat frequently turned aside from the route marked out by his immediate predecessor; either he was not following the trail or he could not discriminate the fresh trail from one a day old. Further, the recognition of critical points, and the fact that the rats frequently ran long distances with heads up—*e. g.*, when carrying food—are evidence against the supposition. These facts together are sufficient to throw the theory out of court.

The conclusion is drawn for the present case only. It is perfectly apparent that animals of this class do follow trails by scent in the right circumstances. These facts point to the complexity and variety of the animal mind, and are a warning against naïvely accepting 'simplest explanations.'

Another possibility in regard to smell is that particular points in the maze may have been associated with definite peculiarities of odor. The constant sniffing and extensive olfactory investigations of the rats lend color to this thought. The experience thus acquired, may, however, influence only the affective tone—connect directly with the emotional tendencies which determine the animal's conduct. Such a relation is indubitable. I found, for example, that putting rats perfectly familiar with the task, into a new maze, differing from the one learned only in *newness*, threw them into extreme emotional excitement. They acted as though the task were absolutely new to them. They were curious, timid, and hesitant; errors were as frequent as in their introductory trial. After finding the food, they continued eagerly exploring and re-exploring the maze. As soon, however, as they had become familiar with the new odors, their former facility returned; they made the journey as quickly and accurately as before. This would not have occurred, had it been necessary for them to establish a new series of smell-position-direction associations. The inference is clear that the effect of smell sensations is general and emotional, rather than that delicate and discrete associations of odors with special positions are set up. The point, however, is not absolutely secure. Probably more conclusive evidence might be obtained by testing rats with olfactory nerves paralyzed.

Sight. Sight is much less relied upon, and, relatively, much less acute than smell and hearing—the psychic organs respectively of food-getting and defence. This corresponds with the poor development of the eye and optic nerve.[1]

[1] The eye of the wild brown rat is better developed than that of the white rat, but the two rats varied slightly in their conduct in the maze.

Several tests were made, the results of which indicated that visual perception played no part in the processes of recognition and discrimination.

1. It was suggested to me that the direction of light, by analogy with Lubbock's[1] experience with ants, might be a factor in the chance of path. Lubbock found that "when the direction of the light was changed, but everything else left as before, out of seven ants, five were deceived and went in the wrong direction." (This was after they had learned their path perfectly, of course.) Fortified by further experimentation, Lubbock concludes that "in determining their course the ants are greatly influenced by the direction of the light."

As the rats did most of their exploring in the dark, and as the brightness element is only one factor in the visual datum, not the total datum as with the insect, it was improbable that this factor should be very influential. Nevertheless, it was made a matter of experiment. Tests were made by having the rats learn the path perfectly with the direction of the light constant. The light was then transferred to the opposite side for a few trials; after which, it was alternated at unequal, though frequent, intervals. The results were: (1) In most cases, change of direction of the light seemed to produce a very slight effect upon certainty and celerity of movement; but hardly more than might occur as normal variations under constant conditions. (2) Some subjects showed absolutely no effect. (3) After the first change the alternation produced no effect. This shows that the effect when it occurred was merely a slight affective disturbance—a retardation, not a change of the cognitive process. Plainly this is a very minor factor.

2. A partial test of the part played by sight in the recognition and discrimination necessary to the formation of special associations at critical points was made as follows: At all such points, bright red posts, ¼ inch diameter, were placed in the middle of the right path a few inches beyond the dividing of the ways. When the rats had learned the path perfectly the posts were removed. Two rats only were tried, the results being *nil*. These rats did not learn the path more quickly; nor did they exhibit the slightest variation in conduct after the posts were removed. It is tolerably clear that visual data, if effective, must be of a more general character. The animal does not hang his association upon a gross and obvious object.[2]

3. Another method of partial experiment suggesting itself was to blindfold the rat after he had learned the path. The evident

[1] Lubbock: Ants, Bees, and Wasps, p. 267 ff. (6th Ed.).

[2] It is improbable that the action had become so habitual as to dispense with what was at first a determining factor in the formation of the association.

objection to this plan is that it would change completely the conditions of attention and emotion. If the subject blundered and failed nothing would be proved. If he did his work about as well as before there would be a negative demonstration of the slight importance of visual perceptions; *not, however, of visual sensation*, for its effect might still be present as visual images co-operating in the mental process.

Fortunately, nature stepped in and performed a conclusive experiment for me. A number of my rats came to me with diseased eyes. Before I discovered this, two of them, an adult male, *X*, and a young female (about 10 weeks old), Y, had become blind. I had already started them learning the maze, with two others, when I noticed their blindness. After the fifth experiment they were totally blind. In the first two experiments distinct impressions—if white rats have such—may have been possible to *X;* and brightness sensation until the fifth. Rat *Y* may have had brightness sensations in the first two experiments, but not later. At this time the general health, vigor and temperament of these rats were unaffected by their malady.

The results of the experiments with these blind rats were so striking that I give them somewhat fully. Until after the ninth trial, the two normal rats were continued with the blind ones. They were then removed, and thirteen more experiments were made with the blind ones. Following that, the latter were tried in the reversed maze. The blind rats learned the original task as well as the normals—all the normals experimented with. Rat *X* in this case learned the path before either of his normal companions. In Exps. 5 and 6 he was first to C, and made fewest errors. In Exp. 7 he made the round in 50 seconds, without error, and with slight hesitation at two points only. In the succeeding 15 experiments he showed practically perfect acquaintance, though occasionally making errors. His conduct in the maze did not differ materially from that of normal rats. He ran in the middle of the galleries, rounded the corners quickly and precisely, and carried on the usual investigations. At critical points there were the same hesitation and indecision manifested as with the normals, by alternately turning each way as if stayed in the grasp of conflicting images. Occasionally he would nose along the several sides before starting on again. This probably was not a direct means of ascertaining the way, for, later, I cut off his feelers, also those of some normals, without any effect upon their ability to find their way.

The results with Rat *Y* were even more interesting, as she was certainly totally blind after Exp. 2. She was somewhat longer in learning the way than *X* and the normals. At

first she was slow and diffident in starting, and less facile in getting about; she ran somewhat gropingly, and frequently almost bumped into the ends of the galleries. These defects soon wore off, and she kept her path and rounded the corners as nicely as the others. Certain errors, however, clung persistently, notably at *2* and *3*. After Exp. 3, she had little difficulty beyond *3*. Until Exp. 11, she went each time to the end of *2* and *3* as mechanically as if these were essential stages of the journey. I began to wonder whether the habit was so firmly fixed as to defy the benefit of chance experience. In Exp. 12, however, *2* was dropped out; in Exp. 13, *3* was dropped, but *2* reinstated. In Exp. 15, *2* and *3* were finally eliminated, and did not reappear. In the last 7 experiments she made no errors and seldom hesitated or showed indecision. This blind rat thus eliminated errors that had become almost automatically habitual. The experiments with the reversed maze[1] gave the only suggestion of importance of the visual factor. The blind rats when first put into the reversed maze were more disoriented and confused than the normals. Not until Exp. 3 did *X* succeed in getting to C.[2] The normals, on the contrary, seemed to have profited by their experience with the other maze. They made better time, fewer errors, and showed less indecision than in the first experiment in Maze I. They fell off badly, however, in the second trial. The discrepancy between the blind and the normals quickly disappeared; in Exp. 5 the blind rat did as well as the normals. So also, in the successive alternations of the mazes, the blind rat perfected his distinct knowledges of the two as quickly as the normals.

This slight superiority of the normal rats, however, does not seem to me to mean that visual data exerted a determining influence. Rather, with the blind rats the motor element was so exclusive in the reproductive process as to make readaptation proportionately more difficult. With the normals sight, though probably contributing no determining data, served to distract attention from the established reproduction. Sight certainly is not a *sine qua non* in the process of experimental reasoning incident to these experiments. Its service is superficial, and may be dispensed with almost without loss. Its office in the essential processes of recognition and discrimination is hardly

[1] The method of experimentation was to transfer the subject, after he had mastered the original maze, to the reversed form—*i. e.*, right and left interchanged. After this reversed form was learned the rat was returned to Maze I. The mazes then were alternated till both were learned perfectly.

[2] Rat *Y* died in Exp. 3, so these data are from observations of Rat *X*.

appreciable. Its forces are deployed in the background of consciousness; they do not get into the forefront of action.

By this process of elimination the conclusion emerges that the tactual motor sensations furnish the essential data for the recognition and discrimination involved in forming the special associations at critical points. How the animal recognizes critical points it is impossible to say. The most reasonable supposition is that in the gradual formation of the motor memory of the entire course, at the established distance-intervals, the conflicting images of turning in one direction or the other spontaneously arise, resulting in indecision—the sign of recognition. There is some positive evidence in support of a distance quality in the animal's image to be remarked below. The machinery of discrimination seems tolerably clear. In any given case it consists of direct association of *the motor image of turning in one direction* with success, and the motor image of turning in the other direction, with failure. This is the explanation in the cases where one alternative is a blind alley. In the cases where the alternatives are longer and shorter we have to suppose an association between direction and distance; between turning in one direction and the distance traversed or *the time consumed.* Perhaps the quality is temporal rather than spatial; or indeed it may be that the temporal and the spatial *qualia* of this modality of sense are undifferentiated in the lower animals. The positive evidence of the distance quality noted above appears in the fact that the rats quickly adopt the shorter road where there is choice of longer or shorter. It has been pointed out that all the rats experimented with learned, sooner or later, to take the shorter road at x. Inasmuch as both roads lead to Rome it is difficult to see why the shorter one invariably should be selected, unless it is known as shorter, or, in other words, unless quicker satisfaction is associated with this path than with the other. It is equally difficult to see in what terms this association could be mediated other than those suggested—a distance or temporal idea in tactual-motor terms.

The fact of the invariable adoption of the 'shorter circuit' was brought out more clearly and forcibly by a special test. A normal and the blind rat X were used. Both had been familiar with both mazes (direct and reversed) for weeks. Their knowledge was as nearly automatic as possible. A path was opened, then, between d and h, by cutting the walls at w and z. A large part of the first (left) half of the journey thus was cut out.

In the first trial (normal rat) the rat went automatically *via* the old route—paid no attention to the new one. He likewise went directly by the opening at z when he came up from e. In the next trial, however, he took the new path unhesitatingly

through *w* and *z*, and turned correctly—*i. e.*, to the right—at *h*. In the third trial he took the new path, turned correctly at *h*, then paused and went half way to *e;* paused here again, made several abortive movements each way, but finally turned correctly and went forward to C with confidence and speed. In the next two trials the right association became pretty well fixed; the new route was learned perfectly and the old abandoned.

The conduct of the blind rat was really striking. In the first trial he did not notice the new path. In the second, however, he selected it after brief hesitation. The experience of the preceding night was thus strikingly effective. Singularly enough, he perfectly acquired the new association more quickly than the normals.[1] After the second trial he rarely went astray. In all three cases, however, the old habit was quickly broken, and a new, more advantageous one established. This preference for the shorter path is difficult to explain except upon the supposition that the path is known as shorter. To charge it up to the animal's "short-circuiting tendency," or his "tendency to eliminate useless movements" is to beg the question. Unless the advantage of the new path over the old is known in some way the old habit would persist simply in virtue of its own inertia. Again we cannot speak of a direct connection between *turning* in one direction and satisfaction; no such association is formed directly. A direct association is admitted; but it is formed only after experience with both paths, and deliberation often repeated between them. It is difficult to see what the association turns upon, if not upon distance-direction ideas of motor origin.

Why should not the repetition of the same motor expenditure establish in the psychophysical organism a path, the conscious concomitant of which is capable of being discriminated from similar feelings of other expenditures, and capable of reproduction under appropriate conditions?

The chief obstacle in the way of realizing to ourselves the existence and character of such representations as those suggested above is our lack of experience with pure tactual-motor ideas. It is a pertinent illustration of the influence of psychophysical limitation. We recognize that tactual-motor experience is fundamental in our own spatial perception; but it is so grown over and obscured by visual experience that it is next to impossible for us to realize in ourselves a pure tactual-motor image. No fusion of elements is more complete than this. The imperfect isolation we are able to give the tactual-motor element in

[1] A second normal was tried with results essentially the same as obtained with the other.

our own representations helps us, however, to imagine the pure idea of this kind. I observe that my own representation of the course through the maze is strongly motor. I find it just as impossible to see the course as a static visual image as to abstract the motor image from the interfused visual elements. I can alternately make one or the other focal, though the motor seems less *real* than the visual. This imperfect and mongrel tactual-motor experience of ours gives, however, a remote suggestion of the quality and feeling of such ideas in their pure condition. When we consider the clearness and definiteness of the spatial ideas of the blind deaf-mutes it ought not to be very difficult to conceive that an animal of poor visual endowment, or of semi-subterranean habits of life, may do a large part of his thinking in tactual-motor terms; and that the content may have a clearness and fullness of meaning hard for our visually over-slaughed minds to appreciate. With no feature of this study have I been so impressed as with the possibilities it reveals of thinking in motor or tactual-motor terms.

In carrying on this study I have profited greatly by aid and suggestions from many persons, and also from many books. I wish especially to express my indebtedness to Dr. E. C. Sanford for the initial suggestion, for ample laboratory facilities, and for continued interest and helpful criticism; to Dr. L. W. Kline for practical suggestions; to President Hall, and the members of his seminary, for salutary and stimulating criticism. The published works which I have found most helpful are those of Professors Lloyd Morgan, Wesley Mills, and Edward Thorndike, and the *Examen psychologique des animaux* of M. Pierre Hachet-Souplet.