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One figure

In the exact experimental work of comparative psychology evidence of visual image formation has been obtained for all of the higher groups of vertebrates, but few investigators have attempted to determine the accuracy of the animal's perception of outlines.

L. J. Cole, (1907) obtained evidence of the perception of size in the frog. Casteel, (1911) working with the turtle, found that it could distinguish slight differences in the breadth and direction of lines, but did not discriminate between similar patterns. For the birds, Porter, (1904-06) has demonstrated the ability of the English sparrow and cow-bird to discriminate printed patterns and, less accurately, tridimensional objects. In his work with the dancing mouse Yerkes, (1907) obtained no reactions to form and concluded that the perception of form has little importance in the activities of the mouse. Waugh, (1910) in similar experiments, obtained only slight evidence of form discrimination and was led to the same conclusion. By L. W. Cole, (1907) the raccoon has been trained to distinguish perfectly between objects of different size and form, square and circular cards, etc. Kinnaman, (1902) found that his monkeys could compare the size of the food boxes used and form some absolute standard of comparison. They also distinguished between vessels of different form but did not recognize differences in printed patterns.

The present investigation has attempted to determine the visual acuity of the rat, making use of the "form and size methods" (Washburn, 1908). Like the mouse, the albino rat is without an area centralis (Chievitz, 1891 and Slonaker, 1897), and the retina contains only rod-like sensory elements. From the likeness of structure and habitat, a similarity of visual function is to be expected.

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APPARATUS AND METHODS

Throughout the greater part of the experimental work a discrimination box, modified after the type designed by Yerkes, (1907), was employed. This box was used by Hoge and Stocking, (1912). A diagram of it is given in figure 1. The box con-

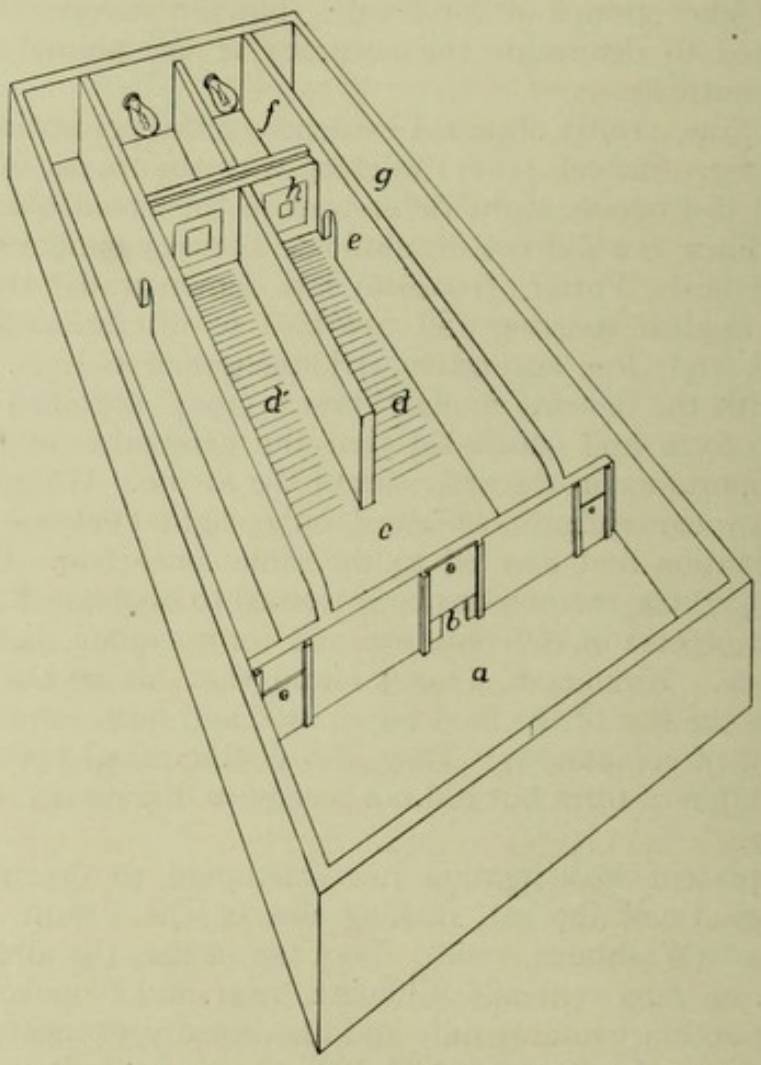

FIGURE 1. Discrimination box. a, Starting compartment; b, sliding door; c, discrimination compartment; d, d', passages wired with electric grill; e, door to food compartment; f, light compartment; g, food compartment; h, reversible frame containing the translucent forms used as stimuli.

sists, essentially, of a starting-room, a, leading by a door into the discrimination compartment, c, in which the choice of two passages is offered to the animal. The forms to be discriminated are placed at the ends of the passages so that the animals must go directly toward them in order to reach the doors leading to the food compartments, g, g. The forms consist of metal plates, pierced by suitable openings and backed by opal flashed glass. They are fastened in a wooden frame, h, which may be lifted out of the box and inverted in order to transpose the stimuli. Sixteen candle power, carbon filament lamps, placed in a compartment, f, behind this frame, illuminate the forms brightly. The passages, d, d, are wired with an electric grill by which punishment may be administered.

Food, given in the compartments g, g, after a correct choice, and punishment, given in the passages after an incorrect one, were used as motives for discrimination. The rats were allowed to run from the starting box to the food compartment and were then lifted back to the starting box. In the first experiments punishment did not seem to give good results and it has been used as a motive only where indicated in the descriptions of experiments.

Since none of the work was quantitative, no regular system was followed in reversing the stimuli, but care was taken that the number of times that the positive stimulus was exposed in each passage should be equal in any given series of trials. In spite of this the animals, especially those which were punished, showed a strong tendency to form position associations, going again and again through one of the passages even when severely punished.

At different times during the experiment some of the rats learned to react to the noise made in reversing the forms, to the position of the experimenter during the trials, and possibly to variations in the time between successive trials. They usually tended to avoid the passage in which they had last been punished, and learned readily to follow simple rhythms of alternation. In experiments with Rat No. 6 it was customary to electrify the punishment grill before admitting the animal to the discrimination compartment, and there is some evidence that she learned to test the grill with her vibrissae before venturing over it.

Whenever any such reactions were discovered, immediate attempts were made to eliminate them, and control series were given to determine their importance in the total reaction. In general, it was only in the more difficult problems that the animals fell back upon these secondary criteria. The sense of smell never seemed to play any part in the reaction.

As a rule, each animal was given 20 trials a day but this number could not be adhered to strictly. With the type of apparatus used, 50 per cent of error indicates that the animals are not discriminating, that their movements are due to chance, and it was found during succeeding experiments that a much lower percentage of error, not more than 25, upon several consecutive days was necessary to give conclusive proof of discrimination. An animal might make 90 per cent of correct choices in a series of 20 trials, but such a high average, if due to chance, never persisted through two consecutive series. The percentage of error is not always a safe measure of the animal's ability to discriminate between the stimuli. It does not take into account the fluctuations of attention or the difficulties of associative and learning processes. For this reason the behavior of the rats in the discrimination compartment has been given special emphasis.

ANIMALS

In the experimental work albino rats alone were used. Trapped specimens of *Mus rattus* proved to be too wild for experimental purposes, and domesticated races of pigmented rats have shown no marked superiority to the albinos in visual discrimination, so no extensive comparison between pigmented and non-pigmented races was undertaken.

The rats used differed considerably in age and in behavior at the beginning of the experiments.

No. 1. Female, 11 weeks old when given this problem; vigorous, active, and stable.

No. 2. Female, from the same litter as No. 1; very large and inactive.

No. 3. Female, from the same litter as No. 1; stunted in growth, very excitable, and easily frightened.

No. 4. Female, about two months old; large and active.

No. 5. Female, from same litter as No. 4; ill during the first part of the experiment, small but very active.

No. 6. Female, age unknown; she had given birth to one litter which she devoured; very tame, accustomed to being handled. Judged from her general behavior, this rat seems to use vision to a greater extent than the others.

No. 7. Female, age unknown; forms position associations very readily.

EXPERIMENT 1. DISCRIMINATION OF FORM

Apparatus: The discrimination box; two standard stimulus plates showing a square and a circle of equal area (56.548 sq. cm.). The experiment was conducted in a darkened room. Rats Nos. 1, 2 and 3 were used. Since they showed no preference for either form, the square was chosen arbitrarily as the positive stimulus. The motive differed for each of the animals.

No. 1. Food after a correct choice only.

No. 2. Food after every trial, punishment after an incorrect choice.

No. 3. Food after correct, punishment after incorrect choice.

During the first part of this experiment no precautions were taken to eliminate other than visual stimuli to which the rats might learn to react. The noise made in reversing the stimuli and other movements and sounds made by the experimenter were thus available to the animals as indices of the passage to be chosen.

Table I, giving the percentage of error in each 100 trials, shows the record made by the animals in 1000 trials. The percentage of error was never small enough to justify the conclusion that the animals were reacting to the difference in the visual stimuli. The occasional low percentages are to be explained by the appearance of reactions to sound, or to other accidental stimuli.

TABLE I

DISCRIMINATION BETWEEN SQUARE AND CIRCLE OF EQUAL AREA. PERCENTAGE OF ERROR IN EACH CONSECUTIVE HUNDRED TRIALS

No. trials	100	200	300	400	500	600	700	800	900	1000	Average
Rat No. 1	47	39	48	45	40	37	47	37	60	53	45.8
Rat No. 2	65	46	54	71	49	59	64	48	52	46	55.4
Rat No. 3	41	37	36	38	43	55	51	43	40	55	43.9
Average	51	40	46	51	44	50	54	43	51	51	48.3

The average percentage of error is slightly below 50 and this may be explained by the training method employed, which frequently allowed the animals to make several correct trials before the stimuli were transposed. The effect of this method appears in the first 500 trials (46.8%) but disappears in the last 500 (49.8%), in which an effort was made to eliminate all secondary criteria by which the animals might regulate their reactions.

Since the rats learned to react to sound and to other accidental stimuli it is certain that they were not indifferent to the motives provided and that their failure to respond to the visual stimuli was not due primarily to a fault in the technique of experimentation. The cause of their failure is to be sought in the nature of the visual stimuli, or in some defect in their visual apparatus. After a few hundred trials the animals became almost machine-like in their actions, the choice of the passage taken usually having a definite relation to the success or failure of the preceding trial. They rarely paused in the discrimination compartment or passages and did not seem to attend to the stimuli. It seemed, then, that the failure might be explained by this inattention and a second experiment was therefore undertaken in the hope of training the rats to attend to the illuminated areas.

EXPERIMENT 2. MOVING STIMULUS

Apparatus: The discrimination box with the forms as in experiment 1. A revolving sector was introduced into one of the light compartments (figure 1, f) between the light and the metal form. The sector was composed of two vanes, each of 45 degrees, and was turned by a small motor at a speed of five revolutions per second, thus interrupting the light 10 times per second and producing a regular flickering. It was expected that this flickering light, simulating movement, would hold the animal's attention, and that, by decreasing the size of the sector and increasing its speed, the factor of movement might be gradually eliminated and the attention transferred to the difference in form. The square and circle were retained as stimuli and the sector was kept constantly behind the square, the forms being reversed as usual.

In the first series of trials given after the introduction of the sector all the rats showed evidences of fear, refusing to go toward

the interrupted light or, at first, even into the discrimination compartment. In accordance with the custom of training against a preference the rats were required to select the interrupted light. After the first 20 trials the animals gave no further signs of attention to the flickering stimulus. Increase or dimunition in speed of rotation produced no change in their behavior. After 200 trials rat No. 2 became stubborn under punishment and had to be removed from the experiment.

As shown in table II, there was no decrease in the per cent of error after 500 trials. The rats did not learn to react to the stimulus although at first they had seemed to be disturbed by it.

EXPERIMENT 3

The size of the sector and its speed of rotation were next increased so that a marked difference in the brightness of the forms was produced.* For rat No. 1 a sector of 270 degrees was used. She learned to react to the difference in brightness and a change to the original speed of rotation did not affect the reaction. The size of the sector was then reduced to 180 degrees and later to 90. Each change was followed by a sudden increase in the per cent of error, then a gradual improvement in discrimination. When the sector was reduced to 75 degrees the rat failed to discriminate and soon ceased to attend to the stimulus (table III). The chief interest of this experiment lies in the fact that by a gradual increase in the similarity of the stimuli the rat could be trained to respond to a difference to which it had formerly given no attention.

EXPERIMENT 4

Since the animals did not distinguish between the square and circle, another experiment, apparently involving a greater difference, was undertaken. A circle, 30 millimetres in diameter, was used as the positive stimulus and two circles, 21.2 millimetres in diameter and 40 millimetres apart in a horizontal line, as the negative. Rats Nos. 3 and 7 were given this problem.

Table IV gives the percentage of error for each 100 trials and shows that there was no discrimination of the stimuli, even after 1000 trials. The animals ran through the discrimination compartment without a pause and never attended to the stimuli.

* Hoge and Stocking (1912), have shown that differences in brightness are discriminated by both albino and black and white rats.

TABLE II

PERCENTAGE OF ERROR IN DAILY TESTS WITH INTERRUPTED LIGHT

Rat No. 1		Rat No. 2		Rat No. 3	
Trials	%	Trials	%	Trials	%
20	40	20	45	20	50
20	35	20	40	20	65
20	45	20	60	20	35
20	35	20	65	20	45
20	40	20	35	20	45
20	30	20	30	20	80
20	55	20	35	20	80
20	30	20	40	20	40
20	35	20	40	20	55
20	30	20	50	20	55
20	35	20	40	20	55
20	45	20	55		
20	50	20	50		
20	50	20	25		
20	50	20	40		
10	50	20	55		
20	40	20	85		
20	50	20	50		
20	45	20	50		
20	45	20	35		
20	45	20	45		
20	60	10	40		
20	45	10	60		
20	45	20	55		
20	90	10	60		
20	70	10	50		
20	50	10	60		
20	80	10	50		
20	40	10	60		
		10	40		
		10	70		
630	47.4	560	59.8	220	55.0

TABLE III

PERCENTAGE OF ERROR WITH LARGE SECTOR. RAT NO. 1

Size of Sector	No. Trials	%
270	20	40
"	20	40
"	20	25
"	20	35
"	20	45
"	20	15
"	20	35
"	20	30
"	20	10
180	20	40
"	20	25
"	20	20
"	20	10
90	10	20
"	20	50
"	20	25
"	20	45
"	10	30
"	20	15
"	20	35
"	20	10
75	10	20
"	20	50
"	20	55
270	20	0
90	10	50
"	10	40
"	10	20
"	10	10
45	10	20
90	10	60
"	10	20
"	10	60
"	10	50
"	10	70
"	10	30
"	10	30
"	10	30
"	10	30
"	10	10
"	10	30
"	10	20
"	10	20

TABLE IV

DISCRIMINATION BETWEEN ONE AND TWO CIRCLES OF EQUAL AREA. PERCENTAGE OF ERROR IN EACH HUNDRED TRIALS

No. trials	100	200	300	400	500	600	700	800	900	1000	Average
Rat No. 7	48	50	54	58	55	59	54	61	54	56	54.9
Rat No. 3	54	47	60	56	62	48	48	47	56	51	53.1

EXPERIMENT 5

This experiment was similar to the preceding, but instead of circles the forms used were two illuminated lines, 2 by 60 millimetres, one horizontal and one vertical. Rat No. 2, at the age of seven months and after about 2000 trials in other experiments, was given this problem After the experiment with interrupted light she had been trained to react to differences in brightness so that, at the beginning of this experiment, she attended to the illuminated forms. After 150 trials she began to show evidence of discrimination, hesitating and apparently looking at the forms before choosing one of the passages.

Table V gives the daily records for 760 trials. After 300 trials there was constantly more than 80 per cent of correct choice, and since control series in which both lines were placed horizontally gave 50 per cent of error, this was taken as sufficient evidence of discrimination. Control series in which the relative brightness of the forms was altered did not affect the reaction, while any great change in the shape of the forms themselves caused a complete failure.

EXPERIMENT 6

When the reaction to the lines was firmly established an attempt was made to determine the animal's ability to distinguish lesser differences. For this purpose two of the standard forms were provided with sliding metal plates, adjustable in two directions, so that the openings could be varied from a narrow line to a square or rectangle. These were first set as lines, 20 by 60 millimetres, and substituted for the horizontal and vertical lines used in the preceding experiment. By shortening and widening the lines the contrast between them could be reduced until both became squares, equal in area.

TABLE V

DISCRIMINATION BETWEEN VERTICAL AND HORIZONTAL LINES. RAT NO. 2

Trials	Per cent Error	Trials	Per cent Error	Trials	Per cent Error	Trials	Per cent Error
10	40	140	30	340	30	560[1]	40
20	40	150	30	360	10	580	15
30	50	160	20	380	10	600	20
40	30	180	40	400	15	620	25
60	50	200	35	420	25	640	20
80	30	220	25	440	25	660	10
90	60	240	30	460	20	680	15
100	40	260	45	480	10	700	20
110	30	280	15	500	5	720	25
120	50	300	15	520	20	740	20
130	50	320	15	540	10	760	10

[1] At this point in the experiment No. 2 developed a bronchial disease which has made her later records somewhat irregular.

Table VI shows the changes made in the form of the stimuli and the percentages of error obtained in this experiment. Rat No. 2 gave certain evidence of discrimination between the 12 by 50 millimetre rectangles, and seemed to recognize the lesser differences without great difficulty.

TABLE VI

DISCRIMINATION OF FORM. RECTANGLES WITH THEIR LONG DIAMETERS AT RIGHT ANGLES

Size of Rectangles	No. Trials	Per cent Error	Size of Rectangles	No. Trials	Per cent Error
2 x 60	20	10	12 x 50	20	25
"	20	10	"	20	20
"	20	15	"	20	10
			"	20	15
12 x 50	20	25			
"	20	25	15 x 40	20	20
"	20	20	"	20	25
"	20	10	"	20	20
"	20	5			
"	20	20	20 x 30	20	10
"	10	10			
"	20	15	25 x 25	20	60
"	20	20			
			20 x 30	20	45
			"	20	60
			"	20	30

The percentage of error did not increase above 25 at any time during the experiment and the fact that no perfect records

were made is due, at least in part, to the state of the animal's health. She suffered at this time from a pulmonary trouble which constantly distracted her attention from the stimuli.

Control experiments showed that the rat was not depending upon brightness, sound, or position in making the discrimination and her behavior in the discrimination compartment offers the best evidence that she was really attending to the visual stimuli. During experiments 1 and 2 she had always hesitated for a long time before venturing from the starting box to the discrimination compartment, finally dashing through to the food box as quickly as possible, avoiding the punishment grill by long leaps. When a marked difference in the brightness of the forms was introduced she began to pause in the discrimination compartment, swaying back and forth between the two passages before choosing. As her proficiency in discriminating differences in brightness increased, the time spent in choosing diminished until the reaction became almost instantaneous. With the greater number of correct choices her attempts to avoid the punishment grill were less marked. With the introduction of the lines as stimuli the hesitation between the passages again appeared, increasing and diminishing gradually after each change in the stimuli.

From the percentages of error it is evident that the animal could distinguish between the narrower rectangles. Her behavior in the discrimination compartment indicates that the discrimination was more accurate than the percentage records would seem to show, since they include all the trials made without regard to accidental distraction of attention. After the first day's work with the 20 by 30 millimetre rectangles, when 18 out of 20 trials were correct, the form of the stimuli was changed as a control. With the new forms there was 60 per cent of error, showing that perception of form was involved in the former reaction, but unfortunately this short interruption was sufficient to break up the association and in the next 300 trials there was 45 per cent of error with complete loss of attention.

EXPERIMENT 7. DISCRIMINATION OF SIZE

Apparatus: The discrimination box; two circles of 30 and 50 millimetres diameter respectively as stimuli. In the type of apparatus used the illumination of the two circular openings

used as stimuli is equal per unit area, but since the flashed glass forms a total diffusing surface it acts as a direct source of illumination for the two passages. Consequently the brightness of the passages differed appreciably, being directly proportional to the areas of the circular openings. For the experimenter the difference in size between the stimuli was so much more evident than the difference in brightness that this latter was not considered at the beginning of the experiment.

Rats Nos. 4, 5 and 6 were used, with food, punishment, and food and punishment as motives. After 200 trials all began to show evidence of discrimination, but it required more than 500 trials to establish the association thoroughly. Even after 700 trials No. 5 was very uncertain in her reactions. Table VII shows the daily percentages of error in this experiment.

TABLE VII

DISCRIMINATION OF SIZE. CIRCLES 30 AND 50 MILLIMETRES IN DIAMETER AS STIMULI

No. of Series	Per cent of Error			No. of Series	Per cent of Error		
	Rat No. 4	Rat No. 5	Rat No. 6		Rat No. 4	Rat No. 5	Rat No. 6
1	45	25	55	23	15	25	40
2	55	60	35	24	20	30	10
3	50	40	45	25	25	25	0
4	45	40	35	26	15	30	10
5	40	45	40	27	20	35	5
6	55	45	35	28	25	20	15
7	55	40	45	29	10	30	20
8	35	70	60	30	20	20	10
9	40	40	20	31	15	35	0
10	45	45	45	32	5	15	20
11	30	35	60	33	10	35	0
12	45	45	50	34	5	10	20
13	40	65	45	35	0	25	20
14	35	25	40	36	10	15	10
15	40	45	45	37	0	25	10
16	45	35	15	38	5	40	20
17	35	35	30	39	0	15	20
18	30	65	40	40	15	20	30
19	40	10	35	41	0	0	10
20	15	55	35	42	0	30	20
21	10	35	30	43	0	30	0
22	30	55	10				

Under the conditions of the experiment it was uncertain whether the animals were reacting to the difference in size of

the circles or to the difference in the brightness of the passages. A few control tests (table VIII) showed conclusively that the discrimination had been made upon the basis of the difference in the brightness of the passage only. The rats had been choosing the larger circle and when the relative brightness of the two was changed they chose always the brighter passage, regardless of the size of the forms. The slight difference in brightness was evidently more easily associated with the motive than was the difference in the size of the circles.

TABLE VIII

CONTROL ON EXPERIMENT 7

Nature of the Stimuli	Rat No. 4		Rat No. 5		Rat No. 6	
	Trials	Per cent Error	Trials	Per cent Error	Trials	Per cent Error
Illumination of larger circle reduced; brightness of passages equalized	50	44	30	60	10	50
Size of circles equal; illumination unequal; animals chose the brighter	10	0	10	10	..	..
30 and 50 mm. circles; the 30 mm. more brightly illuminated	..	..	20	95	10	50
30 and 50 mm. circles; the brightness of the passages equalized by reflected light	10	40	10	60	10	50
30 and 50 mm. circles; the floor of the passage to the 30 mm. illuminated brightly	10	60	10	80	10	60

EXPERIMENT 8

The preceding experiment was continued with the element of brightness eliminated. A 32 c. p. lamp was suspended six feet above the experiment box, so that the two passages were brightly illuminated (table IX, illumination 1). Later, the intensity of this light was increased until the difference in the brightness of the passages was reduced below the human threshold and, consequently, much below that found to exist for the rat (table IX, illumination 4). The 30 and 50 millimetre circles were retained as stimuli.

At first the animals failed to discriminate between the circles, but after 100 trials No. 4 showed evidences of discrimination, and in 200 trials learned to choose the larger circle accurately.

The other rats were slower in learning and required from 600 to 800 trials. When they had learned the problem they were given control series similar to those outlined in table VIII, but in this case the results were quite different. Changes in the relative brightness of the passages and forms did not affect the accuracy of the reaction, while reduction of the difference in size caused an increase in the per cent of error. In order to make certain that the rats were not reacting to the movements of the experimenter a test series was given by another person and although the animals were excited by the change they still made above 70 per cent of correct choices.

TABLE IX

DISCRIMINATION OF SIZE. BRIGHTNESS FACTOR ELIMINATED

Rat No.						Rat No.						Rat No.					
4		5		6		4		5		6		4		5		6	
No. Trials	% Error	No. Trials	% Error	No. Trials	% Error	No. Trials	% Error	No. Trials	% Error	No. Trials	% Error	No. Trials	% Error	No. Trials	% Error	No. Trials	% Error
10	50	10	60	10	40	20	0	10	60	20	45			20	30	20	15
10	30	10	50	10	50			10	30	20	45			20	25	20	20
10	90	10	30	10	50			10	40	20	50			20	25	20	15
10	30	10	50	10	50			10	40	10	30			20	20	20	5
10	20	10	50	10	50			20	50	10	50			20	20	20	10
10	30	10	10	10	50			20	50	10	30			20	10		
10	15	10	50	10	20	Illumination 1								20	10		
10	30	10	20	10	30			10	30	10	50			Ill. 4			
10	20	10	30	10	30			20	75	20	25			20	30		
10	15	10	20	10	30			20	55	20	25			20	20		
20	35	10	50	10	40			20	25	20	10			10	30		
20	10	10	40	10	40			20	60	20	55			10	20		
20	5	10	50	10	40			20	50	20	20			10	30		
20	10	10	40	10	30			20	35	20	15			10	20		
20	10	10	30	10	60			20	45	20	25			10	10		
20	5	10	40	10	70			20	20	20	10			10	90		
Illumination 4								20	20	20	10			10	50		
20	20	10	50	10	50			20	35	20	25			10	20		
20	10	10	20	20	50			20	15	20	10			10	30		
10	10	10	60	20	45			20	15	Ill. 4							
												300.		790.		630.	

EXPERIMENT 9

As soon as definite evidence of size discrimination was obtained an attempt was made to determine how small a differ-

ence the animals could distinguish. The size of the smaller circle was increased to 40 millimetres, the 50 millimetre circle being retained as the positive stimulus. Rat No. 4 learned to distinguish between these circles, but after 200 trials grew inattentive. Punishment was introduced to strengthen the motive and was continued throughout the third 100 trials (table X). The punishment was not associated with the stimulus and served only to confuse the rat so its use was abandoned. After 200 more trials the association was restored, but further attempts to reduce the difference between the stimuli produced an uncertain reaction. The smallest difference which the rats can distinguish, under the conditions of the experiment, is about two-fifths of the area of the larger circle.

TABLE X

DISCRIMINATION BETWEEN CIRCLES OF DIFFERENT SIZE. RAT NO. 4

Size of Circles	Trials	Per cent Error	Size of Circles	Trials	Per cent Error
50 and 30	10	0	50 and 30	20	15
50 and 40	20	15	" " "	20	40
" " "	20	20	" " "	20	20
" " "	20	10	" " "	20	20
" " "	20	25	" " "	20	20
" " "	20	0	" " "	20	20
" " "	20	20	" " "	20	20
" " "	20	10	" " "	10	10
" " "	20	15	" " "	20	10
" " "	20	25			
" " "	20	40	50 and 40	10	30
" " "	20	25	" " "	10	30
" " "	20	35	" " "	10	30
" " "	20	30	" " "	10	20
" " "	20	50	" " "	10	10
" " "	20	60			
			50 and 45	20	60
60 and 30	20	5			
50 and 30	20	40			

EXPERIMENT 10

In the preceding experiments it appeared that the principal fault in the method of experimentation lay in the fact that the rats did not attend readily to the stimuli. Those which learned to react to differences in size or form had first learned to attend to brightness differences. From this it seemed prob-

able that animals which were attending to the stimuli and reacting to differences in size might be trained without great difficulty to attend to differences in form.

Two forms, a square of 1600 square millimetres area and a circle of 706 square millimetres, were substituted for the forms used with rat No. 6 in experiment 9. The animal (No. 6) discriminated between these immediately, choosing the square. The area of the circle was gradually increased to 1200 square millimetres at which point the rat failed to react. This process of starting with a wide difference in area and gradually decreasing it was repeated three times, but whenever the area of the circle became more than three-fourths that of the square the rat ceased to react to the difference. After 600 trials there was no evidence that she could discriminate form.

With rat No. 4 a six pointed star was used as the positive stimulus, a circle of varying size as the negative. No. 4 chose the star so long as the difference in size was great, but when the area of the circle became more than three-fourths that of the star, the reaction became uncertain or broke down entirely.

With rat No. 5 two circles of a combined area of 706 square millimetres area (see experiment 4) were used as the negative stimulus, and a square of varying area as the positive. Starting with a square of 3600 square millimetres area, the area was reduced to 1225, at which point discrimination failed. This was repeated twice but the reaction always became uncertain when the difference in size became less than the area of the smaller form.

Later, with rat No. 6, a 40 millimetre square was used as the positive stimulus, and the negative stimulus was varied in form, its size being kept less than three-fourths that of the square. Circles, triangles, and various other forms were used. After the first few changes the rat was no longer disturbed by alterations in the form of the stimulus and chose the larger without hesitation. But whenever the difference in size was reduced below the threshold (experiment 9) she fell back upon position associations and failed to discriminate. In several of these series the rat chose the form of greater area, even when the other appeared larger when viewed as a unit of light and shade.

From these experiments it appears that the rats, in discriminating between objects of different size, do not perceive or do

not attend to differences in form. Further data, obtained from rats 4 and 6 when offered a choice of two new forms of unequal size, support this view.

EXPERIMENT 11

Since the discrimination box places the animals under somewhat unnatural conditions a few tests were undertaken under an environment more nearly approaching the normal.

(a) Two cardboard food boxes were constructed, the one rectangular, the other pyramidal in form and having small openings in the sides to admit the rats. The exposed faces of the boxes were of equal area (128 square centimetres) but, owing to the sloping surface of the pyramid, they differed somewhat in brightness. Food was given in only one of the boxes and they were interchanged irregularly to avoid position associations.

Of the three rats required to choose between the boxes not one showed any evidence of discrimination after 150 trials. All formed position and rhythm associations but did not distinguish between the boxes in any way.

(b) Rat No. 1 was trained to go to a large square of flashed glass supported in an upright position upon the floor of the laboratory. After a few trials she learned to run directly to the square from a distance of two or more feet, passing behind the glass to get a bit of food. When this association was established a small piece of glass, one centimetre square, was placed beside the larger (12 by 12 centimetres). The rat sniffed at the small glass only once, then gave it no further attention. When a plate of 25 square centimetres area was substituted for the smaller square, the rat became confused and failed to choose the larger. After 40 trials, however, she began to avoid the small square and made a record of 17 correct choices in 25 trials. A rectangle of half the area of the larger square was then used as the negative stimulus. In the first 20 trials the rat made only five per cent error, then became frightened and in 200 trials since has shown no evidence of discrimination.

From this experiment it appears that the rat can distinguish great differences in size without difficulty. With slighter differences, however, the dependence upon kinaesthetic sensations appears, just as in the discrimination box, and learning does not seem to be any more rapid. The objection to the unnatural-

ness of the discrimination apparatus does not seem, then, to be a very serious one.

EVIDENCE FROM THE RAT'S BEHAVIOR IN THE DISCRIMINATION COMPARTMENT

In the descriptions of the experimental work the percentage of error has been employed to express the rat's ability to discriminate, since a great number of correct choices forms the most certain evidence, but in all the experiments, where positive results were obtained at all, the rats showed a recognition of the difference between the forms before the percentage of error was reduced below 50. In the unsuccessful experiments, after the first 100 trials, the animals became almost machine like in the regularity of their movements. There was seldom a pause in the discrimination compartment and the choice of a passage usually followed some definite rhythm. In experiments 3, 5 and 7 the beginning of discrimination was marked by long hesitation with a swaying back and forth between the passages. In the early stages of learning a correct choice more frequently followed where the animal hesitated than when it made a rapid choice. Later in the experiment choice by negation seemed to become the more important method of eliminating error. The rats chose a passage quickly, and if it were wrong, turned back when about eight inches from the stimulus. Choice by affirmation never seemed to be very effective, even with the best trained rats They would frequently make a correct choice, then hesitate, turn back, and compare the forms.

When responding to visual stimuli they showed a careful attention to the illuminated forms, frequently returning from the food compartment to sniff at them after an incorrect choice. Failures more often followed after evident inattention.

At the introduction of any new element into the discrimination box, as when swinging doors were placed in the food boxes or when the passages were repainted, the rats became very much excited, refusing to leave the starting box or to approach the new object. This type of behavior was very marked in experiment 2 when the revolving sector was introduced, and shows unmistakably that the rats perceived the moving shadow, although they did not associate it with the motive. Changes in the brightness relations of different parts of the box were followed similarly by confused reactions.

The responses to sudden changes in the form of the stimuli are of importance as evidence of discriminating ability. Rat No. 6 was choosing the larger of two circles accurately (100%). Two squares of the same area, respectively, as the circles, were substituted for the circles and during the next 10 trials No. 6 was greatly disturbed, running in and out of the starting box, creeping a little way down the passages, then turning back. She attended to the squares as to something new. There had been no noise to account for this behavior and it is not probable that the new forms had any peculiar odor, so it seems that the rat must have been disturbed by the change of form.

This is only one instance of a type of behavior which appeared, to a greater or less extent, throughout all the experiments whenever the form of the stimuli was changed. It suggests that the animals perceived the difference, although they never associated it with the motive, and raises the question whether the discrimination method offers a fair test of the animal's discriminative ability.

SUMMARY OF RESULTS

In all the records there is a constant deviation in the percentage of error, and a series of 20 successive correct trials is very rare. Sudden increases in the number of mistakes may frequently be explained by the physical condition of the animals. If they are fed too much or too little, their attention to the stimuli is affected and the percentage of error increases. When punishment is used, the rat's fear of the punishment grill after too severe a shock causes irregularities in the records.

Making allowance for such deviations, the selection of the vertical line 164 times in 200 trials (experiment 5) proves that rat No. 5 could distinguish between the vertical and horizontal lines. In discrimination of size, the record of only 14 mistakes in 150 trials shows that rat No. 4 could discriminate between the 30 and 50 millimetre circles.

The number of animals used in the experiments has been small, necessarily, since the time required for each series is considerable. The rats show marked individual differences and all vary from day to day in their attention to the problem. The quantitative results are therefore only approximate. The tests for the threshold of form discrimination have been carried scarcely far enough to give definite results, and the data at

hand are confused by the illness of the rat (No. 6) but it seems probable that she could distinguish between the 20 by 30 millimetre rectangles used in experiment 6. The difference between these forms is scarcely greater than that of the stimuli used in experiments 1 and 4, so this difference must lie somewhere near the threshold for the conditions given.

In the discrimination of size the records of experiments 9 and 10 indicate that the rat can distinguish a difference of one-fourth the area of the larger circle (2000 square millimetres). Reduction below this limit caused uncertainty of reaction and loss of attention. In addition to their ability to compare and choose between the stimuli, the rats are able to fix upon a rough standard of size. In choice by affirmation and negation they tended to go toward a circle of more than 40 millimetres diameter and to avoid one of less than 30 millimetres. But when both circles were made larger than this standard the rats still chose the larger of the two by comparison.

The long failure to react to the interrupted light in experiment 2 suggests that the factor of movement may play a less important part in the activities of the animals than is generally supposed; that an accustomed moving object is no more effective in catching and holding the attention than is a stationary one.

THE NATURE OF THE RAT'S IMAGE PERCEPTION

The rat perceives brightness differences readily, but ordinarily without attention to the nature of the image. Animals which have been trained to go to a white food dish will run to any white object. Absolute size is not so easily recognized, but greatly different areas are distinguished without difficulty. The perception and recognition of form seem to be most difficult for the animal and to require an unusually close attention. In these respects the rat's visual perceptions resemble closely human perception in the extreme peripheral field. Brightness is most evident and size is more readily perceived than form.

TRAINING METHODS

The work of Hoge and Stocking, (1912) indicates that punishment is more effective than reward as a motive for visual discrimination. In the present experiments it was found that, with the more difficult problems, punishment as a motive had

serious disadvantages. With the dancing mouse Yerkes finds punishment to be more efficient than hunger. But unlike the dancing mouse, the adult albino rat is inactive and so a strong motive must be used to induce it to go through the discrimination box. Food furnishes practically the only available motive and must be used almost constantly if the time of reaction is to be kept within convenient limits.

When punishment is introduced in connection with food there is an immediate slowing of the reaction. As a general rule this is evidenced by a hesitation in leaving the starting compartment rather than in choosing one of the passages. The animals show a tendency to go through the discrimination compartment and passages in as few leaps as possible, frequently determining their direction before leaving the starting box.

The difficulty in regulating the severity of the punishment forms the chief objection to its use. The rats differ greatly in sensitivity to the current; No. 3 showed evidence of pain with a shock which the experimenter could not detect, while No. 2 gave no reaction to a current many times as strong. The same rat also differs in sensitivity at different times, and a single instance of too severe punishment is apt to lead to the formation of position habits which can be broken up only with the greatest difficulty. In a difficult problem, with long continued failure to discriminate, the animals become stubborn under punishment and may refuse to leave the starting compartment. For these reasons the use of punishment was almost entirely abandoned. In one case only, that of rat No. 6, was it retained in all the experiments. Her record is not greatly superior to that of the others, although in many ways she appears to be the most intelligent of the group.

LITERATURE CITED

CHIEVITZ, J. H. 1891. Ueber das Vorkommen der Area centralis retinae in den vier höheren Wirbelthierklassen. Arch. f. Anat. u. Entwick., Heft IV, V, und VI.

SLONAKER, J. R. 1897. A Comparative Study of the Area of Acute Vision in Vertebrates. Journ. of Morph., Vol. 13, p. 445.

KINNAMAN, A. J. 1902. Mental Life of two Macacus rhesus Monkeys in Captivity. Amer. Journ. Psych., Vol. 13, p. 98.

PORTER, J. P. 1904. A Preliminary Study of the Psychology of the English Sparrow. Amer. Journ. Psych., Vol. 15, p. 313.

PORTER, J. P. 1906. Further Study of the English Sparrow and other Birds. Ibid. Vol. 17, p. 248.

COLE, L. J. 1907. An Experimental Study of the Image-forming Powers of Various Types of Eyes. Proc. Amer. Acad. Arts and Sciences, Vol. 42, p. 335.

COLE, L. W. 1907. Concerning the Intelligence of Raccoons. Journ. Comp. Neur. and Psych., Vol. 17, p. 211.

YERKES, R. M. 1907. The Dancing Mouse. New York: The Macmillan Co.

WASHBURN, M. F. 1908. The Animal Mind. New York: The Macmillan Co.

WAUGH, KARL. 1910. The Role of Vision in the Mental Life of the Mouse. Jour. Comp. Neur. and Psych., Vol. 20, p. 549.

CASTEEL, D. B. 1911. The Discriminative Ability of the Painted Turtle. Journ. of Animal Behavior, Vol. 1, No. 1, pp. 1–28.

YERKES, R. M. and WATSON, J. B. 1911. Methods of Studying Vision in Animals. Behavior Monographs, Vol. 1, No. 2

HOGE, M. A. and STOCKING, R. J. 1912. A Note on the Relative Value of Punishment and Reward as Motives. Journ. of Animal Behavior, Vol. 2, No. 1, p. 43.