NOTES ON LIGHT DISCRIMINATION IN THE DOG¹

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I. INTRODUCTION

1. *Statement of problem.* This investigation was undertaken for the purpose of determining the threshold of brightness discrimination in the dog. The threshold is arbitrarily defined as the least difference in illumination of a standard and a variable light which the dog can discriminate without error in thirty consecutive trials.

2. *History of the present study.* The study was conducted in the Psychological Laboratory of Indiana University during the year 1915. Four dogs were used at the outset of the experiment: a thoroughbred cocker spaniel, age three and one-half years; two thoroughbred fox terriers, age four months at the beginning of the experiment; and a mongrel, about six years of age. Soon after the experimental work was initiated the cocker spaniel contracted a severe case of distemper which made him useless for further study. The mongrel failed to form the discrimination habit and, finally, after a long period of fruitless training, was discarded. The results to be presented herein were taken, for the most part, from the study of the fox terriers, which proved to be fairly satisfactory subjects.

Following the work with the dogs, ten human subjects were tested in the discrimination problem under conditions of discrimination similar to those set up for the dogs. The results of only three of them are relevant to this study. From these tests comparative data on the limits of discrimination were obtained.

¹ This study was suggested and directed by Dr. M. E. Haggerty, to whom I am indebted for the use of technique and apparatus devised and employed by him in an unpublished study of light discrimination in the dog.

3. *Previous studies in discrimination in the dog.* Vision in the dog has been studied more extensively than any other sensory function. Experiments have been conducted to test its ability to discriminate colors, brightness differences, size, form, and patterns.

In many of the early studies on color vision in dogs the experimenters failed to differentiate brightness from hue; hence conclusions drawn as to the presence or absence of color vision are unreliable. The studies of Graber,² Gates,³ Himstedt,⁴ and Nagel are subject to this criticism.

Colvin and Burford,⁵ attempted to control the brightness factor in testing for color vision, but their control rests on the assumption that the colored papers used have the same brightness values for the dog as for man. The validity of this assumption has been questioned by other experimenters because of the lack of experimental data to substantiate it. Their results which indicate that dogs unquestionably discriminate colors and that they have remarkable keenness in fine color discrimination are, therefore, inconclusive in the absence of adequate control of the brightness factor.

Probably the best study that has been reported on color discrimination in the dog is that of Smith.⁶ In this investigation the brightness factor was controlled by using colored papers of equal brightness as tested by the flicker method. Seven dogs were used in the experiment, but only one completed the whole series of tests. Zimmermann's colored papers and Nendel's grays were used as stimuli. From the results of the study Smith concludes that the dogs seemed to have a very imperfectly developed sensitivity to color differences: and that, owing to the rudimentary character of this sensitivity and

²Grabner, Vitus. Grundlinien zur Erforschung des Helligkeits und Farbensinnes des Tiere.

³Gates, Elmer. The Science of Mentation.

⁴Himstedt, V., and Nagel, W. A. Versuche über die Reizwirkung verschiedener Strahlenarten auf Menschen und Tieraugen.

⁵Colvin, S. S., and Burford, C. C. The Color Perception of Three Dogs, a Cat, and a Squirrel.

⁶Smith, E. M. Some Observations Concerning Color Vision in Dogs, p. 119.

the instability of reactions to colors, this sensitivity can play only an unimportant or secondary rôle in the life of the dog when other factors such as brightness or position are operating.

Orbeli,⁷ using the method of Pawlow, found no evidence to support the belief that dogs can discriminate on the basis of color.

Up to the present time studies on the keenness of brightness discrimination have given us only a vague idea of the degree of sensitivity of the dog's eye to differences in brightness. Discrimination of gray papers has proven to be too crude a method for establishing threshold values, although it serves very well to demonstrate the fact that the dog can discriminate readily on the basis of brightness differences. Field observations also substantiate the view that the dog is sensitive to slight changes in brightness and indicate that this sensitivity plays an important rôle in the daily life of the dog.

Pattern discrimination has recently been tested by Johnson⁸ by means of a modified form of the Yerkes-Watson brightness apparatus. The results of his experimental work were inconclusive; the experimenter thinks, however, that the dogs indicate a low degree of sensitivity to details in pattern.

The chief facts that have been gathered by the various kinds of experimental work in discrimination in the dog may be briefly summarised as follows: Contrary to popular opinion, the dog possesses only very rudimentary sensitivity to colors and depends very little, or not at all, on color distinctions in daily life. The dog readily detects slight differences in brightness and is able to discriminate between objects differing only in form and in size. The dog is probably not highly sensitive under laboratory conditions of experimentation to details of pattern such as those presented by the Johnson-type of experiment.

II. TECHNIQUE

1. *Description of apparatus.* The apparatus used to test the discrimination of dogs consisted of two parts: the Yerkes-Watson

⁷ Orbeli, L. A. *Réflexes conditionnels du côté de l'oeil chez le chien.*

⁸ Johnson, H. M. *Visual Pattern-Discrimination in the Vertebrates.*

brightness apparatus;⁹ and a control box¹⁰ essentially similar, in general plan, to that described by the authors, but built especially for the testing of dogs and adapted to the needs of the present experiment. The plan of the control box is shown in figure 1.

FIG. 1. CONTROL BOX

The frame of the box is rhomboidal in shape with its non-parallel sides equal in length. Its sides, partitions, and frame-

⁹ Yerkes and Watson. *Methods of Studying Vision in Animals*.

¹⁰ Devised and used by Dr. M. E. Haggerty. Study unpublished.

work or cover are made of white pine lumber; the floor, of seasoned walnut. The top and front wall are covered with one half inch mesh wire netting. A heavy black broadcloth screen is interposed between the experimenter and the front of the box to prevent the dog from seeing the former during the time of discrimination. All parts of the box are painted with oil and lampblack of a dull velvet black shade. Light reflected from the walls of the cage is barely perceptible to the human eye. With less than 1 c.p. difference in the illumination of the two light windows, however, the difference in the amount of reflected light in various parts of the cage is wholly imperceptible to the human eye.

On the floor of the box is a punishment grill consisting of oxidized copper wires stretched parallel with each other. These wires are attached at one end to the wooden framework of the floor of the box and at the other end to a steel plate extending along it. At each end they are alternately attached to the wood and to the metal plates. The plates are in circuit with the terminals of an induction coil whose primary is connected with a storage battery. A switch placed in the circuit at a point convenient for operation by the experimenter enables him to give a slight electric shock to an animal standing on the grill at any place in the control box. The floor of the box is covered with velvet black broadcloth, the surface of which reflects very little light.

The control box is divided into four compartments: a starting compartment (C); a discrimination chamber (C_1); and two alley-ways (A and A_1). By way of the latter, the dog may return to the starting compartment after leaving the discrimination chamber. The entrance to the starting compartment from the alley-ways is controlled by Doors D_1 and D_2 . Entrance to the discrimination chamber is effected through the doorway at D . Here there is a sliding door made of a heavy metal plate enclosed in a wooden frame. When the metal plate, which, in place, completely obstructs the passage way, is released it sinks noiselessly in its frame to a position beneath the floor of the box. Partition prevents rays of light from the

two light windows L and L_1 from mingling until at a distance of approximately 20 inches from the windows. This partition fits snugly against the stimulus adapter of the light box and stands midway between the windows.

2. *Calibration of lights.* The light sources in the light box were 225-Watt, 110-volt Mazda lamps. Throughout the investigation a constant voltage of 105 was maintained. The intensity of illumination of one of the two light windows was held at 1 c.p. (Hefner units). In the discussion that follows this window is referred to as the *standard light*. The other window was always illuminated with an intensity greater than 1 c.p. and, in the course of the experiment, was changed by small amounts so that its intensity, with each adjustment, more nearly approximated that of the *standard light*. To this window the name *variable light* is given. During each discrimination trial the light window on one side of the light box was illuminated with an intensity of 1 c.p.; on the other side the window was illuminated with an intensity somewhat greater.

By the use of a Leonard-Weber photometer¹¹ the position was determined for each lamp in the light box at which it illuminated the light window with an intensity of 1 c.p. in a perfectly dark room. With this position known for each lamp, it was then possible to calculate, by the usual photometrical formula, the position that would illuminate the window with any other desired intensity. From time to time the intensities of the light windows was determined to guard against slight changes in the intensities of the light sources arising from deterioration through use.

3. *Training the dogs to discriminate.* A great deal of care and time was devoted to the early training periods in order to establish stable habits of discrimination. *The success of such experiments with animals depends in large measure upon the persistence of discrimination habits when the brightness differences are small and therefore not easily discerned.*

The first step in the training process was that of teaching the dog to make, immediately upon the release of the door at D

¹¹ Stine, Wilbur M. Photometrical Measurements, p. 80.

(see fig. 1) a circuit—leaving the starting compartment, going through the discrimination chamber, into one of the alleys, and thence returning to the starting compartment. While this habit was being formed the illumination of the light windows was kept identical. All lights in the room were turned off and such noises as those made by the shifting of apparatus and the induction coil were introduced at this time in order that the dog might become thoroughly accustomed to them.

When this habit was thoroughly established, the lights in the light box were so adjusted that the illumination of the light windows presented a marked difference in intensity—approximately 35 c.p. The dog was then trained to go to the alley on the side of the darker light. The doors at D_1 and D_2 were opened to allow his return from the alleys to the starting compartment only on the side of the *standard light*. When he chose the wrong alley he was punished by means of the grill and made to turn back and enter the alley on the side of the *standard light*.

The standard and the variable lights were shifted from side to side according to a rather complicated schedule made out in advance of the training and followed throughout the study. The order of shifting was of such complexity that the animal could not learn this order and thus avoid the necessity of discrimination in making the correct responses. Table 1 gives the order of tests used. The trials were given in series composed of fifteen tests. A complete set of trials consisted of twelve such series so arranged that the standard and the variable lights appeared an equal number of times on either side. When a complete set of trials had been given, the set was repeated, beginning with the first series and running through the entire set as before. Each day, excepting Sunday, from two to three series (30 to 45 trials) of tests were given each dog. Testing was usually done between the hours of 2 and 5 p.m.

Care was exercised to prevent the animal from detecting the position of the standard and the variable light on any basis other than the difference in illumination. The experimenter was not visible to the dog while discriminations were being made. Noises involved in the shifting of the lights was reduced to a

minimum, and, prior to each trial, the same amount of shifting was done whether or not the actual positions of the lights were changed. To insure thorough darkness adaptation the dogs were confined in the dark room for a period of from ten to fifteen minutes before the first discrimination test was given.

After the animal had perfected the habit of choosing the alley-way on the side of the standard light so well that thirty consecutive errorless discriminations were made, this habit was employed in finding the threshold of discrimination. The lamps in the light box were so placed that the intensity of the *variable* light was 3 c.p. giving an intensity difference of 2 c.p. between it and the *standard light*. The dogs were required to

TABLE 1

Position of the standard light during 180 trials

L = Standard light on left side. R = Standard light on right side

R	L	R	R	L	L	R	L	R	L	L	R	R	L	R
L	R	L	L	R	R	L	R	L	R	R	L	L	R	L
R	R	L	L	R	L	R	R	L	L	R	L	R	L	L
L	L	R	R	L	R	L	L	R	R	L	R	L	R	R
R	L	R	R	R	L	L	L	R	L	R	R	L	L	R
L	R	L	L	L	R	R	R	L	R	L	L	R	R	L
R	R	L	L	R	R	L	L	R	L	R	R	L	L	R
L	L	R	R	L	L	R	R	L	R	L	L	R	R	L
R	L	R	R	R	L	L	R	R	L	L	L	R	L	R
L	R	L	L	L	R	R	L	L	R	R	R	L	R	L
R	L	R	L	R	R	L	L	R	R	L	L	L	R	R
L	R	L	R	L	L	R	L	L	R	R	R	L	L	R

choose the alley-way on the side of the *standard light* as in the preliminary training period and were punished (electric shock) for failures. They were required to make consecutively thirty errorless discriminations before proceeding from one problem to another problem in which the difference in the illumination of the two lights was somewhat reduced. They worked independently and were given problems involving a lower discriminable difference as soon as a given problem had been completed.

III. RESULTS

1. *Fixation of discrimination habit.* Table 2 gives a summary of the trials and the responses given by the mongrel and the

two fox terriers during the training period required to establish the habit of discrimination.

The young female showed evidence of discrimination after approximately 225 trials, but 150 additional trials were required to so perfect the discrimination habit that thirty consecutive errorless choices could be made. The young male required more trials than the female before signs of discrimination appeared. The first clear evidence of his discrimination came after 345 trials. There were given 210 additional trials before thirty errorless choices were made. The mongrel failed completely to give signs of discrimination during 720 trials. A few days after training was begun, he showed a tendency to go to the left alley irrespective of the position of the standard light. This tendency became habitual and persisted until the course of

TABLE 2

Summary of trials given leading to the fixation of the discrimination habit

DISCRIMINATION DIFFERENCE	ANIMAL	TOTAL NUMBER OF TRIALS	RIGHT CHOICES	WRONG CHOICES	WRONG ON RIGHT	WRONG ON LEFT	PER CENT OF ERROR
35 c.p.	Young female..	375	264	111	55	56	29.8
	Young male...	555	361	194	143	51	35.0
	Mongrel.....	720	369	351	63	288	48.7

training for this animal was ended. The persistence of this *left-alley* habit resulted in a relatively larger number of errors on the left side than on the right side, as is shown in the table of errors of this animal. Of a total of 351 errors, 82 per cent were made by his going to the left alley and only 18 per cent by going to the right side. An alternation habit or random choice without discrimination would have resulted in approximately 50 per cent of the errors being made on each side.

It was necessary to give a large number of trials to the young animals after the first evidence of discrimination was manifested before thirty consecutive errorless choices were made. The records for the last 150 trials for each of the three dogs is given in table 3. An average of approximately one error for each series of 15 trials was made during the last ten test series in the case of the young animals. The number of errors during the

TABLE 3
Records of the last 150 trials

ANIMAL	NUMBER OF TRIALS	RIGHT CHOICES	WRONG CHOICES	WRONG ON RIGHT	WRONG ON LEFT	PER CENT OF ERROR
Young female.....	150	139	11	2	9	7.3
Young male.....	150	140	10	5	5	6.7
Mongrel.....	150	182	68	9	59	45.4

TABLE 4
Summary of discrimination records for female dog. Thirty consecutive errorless choices taken as criterion of discrimination with each intensity. Chose standard (darker) light. Intensity of standard light is 1 c.p. throughout the descent

DIFFERENCE IN INTENSITY OF STANDARD AND VARIABLE LIGHTS (KEPNER UNITS)	NUMBER OF TRIALS	RIGHT CHOICES	WRONG CHOICES	WRONG ON RIGHT	WRONG ON LEFT	PERCENT OF ERROR
2.0 c.p.	225	200	25	14	11	11.1
1.5	105	100	5	2	3	4.7
1.0	90	86	4	1	3	4.4
0.5	45	43	2	1	1	4.4
0.4	330	272	58	22	36	17.2
0.3	315	208	107	33	74	33.9

Position habit established with total loss of discrimination habit at a difference of 0.3 c.p. Returned to a difference of 0.5 c.p. to re-establish the habit

0.5	45	40	5	4	1	12.5
0.4	285	239	36	17	29	16.1
0.375	75	67	8	4	4	10.6
0.350	75	66	9	2	7	12.0
0.325	30	30	0	0	0	0.0
0.3	60	54	6	4	2	10.0
0.28	90	77	13	4	9	14.4
0.26	60	54	6	2	4	10.0
0.24	75	66	9	7	2	15.0
0.22	60	56	4	2	2	6.6
0.2	90	82	8	7	1	8.9
0.18	60	55	7	4	3	11.6
0.16	90	78	12	7	5	13.3
0.14	105	87	18	12	6	17.1
0.12	300	201	99	52	47	33.0

Descent stopped at this difference. Apparently near the point of just perceivable difference. Returned to 14 c.p.

0.14	210	173	37	27	10	17.6
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last 150 trials with the mongrel are about the same as the number at any time preceding. There is no evidence of fixation of the discrimination habit in his case.

2. *Discrimination tests with female dog.* Table 4 gives in summary form the records of the female dog for each discrimination series (15 trials) with problems graded in difficulty from a discriminable difference of 2 c.p. to a difference of 0.12 c.p.

The habit of discrimination broke down when this animal was discriminating a difference of 0.3 c.p. After 315 trials had been given without indication of her regaining the discrimination habit in sufficiently stable form to insure her making thirty perfect choices, it seemed advisable to return to a simpler problem. The difference in the intensities of the standard and the variable lights was raised to 0.5 c.p., a difference that she had previously discriminated with ease. During the first series of 15 tests, after the change in intensity, she regained the discrimination habit, and discriminated the next two series without error. Hereafter the amount of reduction of the intensity of the variable light, at each succeeding step toward the threshold, was made very small. Under this condition the habit of discrimination persisted, with only temporary disruptions, until a difference of 0.12 c.p. was reached. The habit, at this problem, became less stable than usual and appeared to be on the verge of breaking down. To avoid the latter, the difference in intensity was raised to 0.14 c.p.—the least difference previously discriminated. She again made thirty perfect discriminations at this difference. It is evident from these results that the least discriminable difference between the standard light with an intensity of 1 c.p. and the variable light of greater intensity is less than 0.14 c.p. for this dog. It is probably as low or lower than 0.12 c.p. For if the discrimination habit had remained stable with this latter difference it is almost certain that thirty perfect choices would have been made after further practice.

Evidence of her ability to discriminate a difference of 0.12 c.p. is found in the detailed records of her early discriminations, when the habit was relatively stable, at this difference in intensity. In one series of 15 trials the per cent of error was but

15.3. In three such series 20 or less per cent of error was made. In two consecutive series 23 of the 30 choices were correct, giving a per cent of error of 23.3. In three consecutive series (45 trials) the per cent of error was 25.6. Random choice would not give that degree of accuracy. In 75 consecutive trials the per cent of error was 26.5—a per cent which closely approximates the criterion for positive discrimination set by Yerkes in his study of the dancing mouse. His criterion is defined in the following quotation: "Anything (referring to errors) below 40 per cent is likely, however, to be the result of ability to distinguish the brighter from the darker box. To be on the safe side we may agree to consider 25 wrong choices per 100 as indicative of a just perceivable difference in illumination. Fewer mistakes we shall consider indicative of a difference in illumination, which is readily perceivable, and more as indicative of a difference which the mouse cannot detect."¹²

If this criterion is applied to her records of 0.12 c.p. intensity one may safely conclude that the just perceptible difference is somewhat lower than 0.12 c.p.

3. *Discrimination tests with male dog.* Table 5 presents a summary of the male's records for a series of discrimination tests approaching the threshold of discrimination.

The habit of discrimination broke down three times during the work with this dog and finally became so unstable for problems involving difficult discriminations that the work was brought to an end before the least perceptible difference was found. The first disruption of the habit came while he was attempting to discriminate a difference of 0.1 c.p. Upon returning to a difference in intensity of 0.5 c.p., his confusion was still manifest; hence the difference was raised to 1 c.p. After five series of trials with gradually decreasing numbers of errors, two perfect series were discriminated and the descent toward the threshold was renewed. The habit of discrimination persisted this time until a difference of 0.4 c.p., was attempted; here again it broke down. Upon returning to the old problem of 1.c.p. difference, the habit was re-established only after a long period of training.

¹² Yerkes, R. M. *The Dancing Mouse*, p. 123.

TABLE 5

Summary of discrimination records for male dog. Thirty consecutive errorless choices were taken as the criterion of discrimination with each difference in intensity. Chose standard (darker) light. Intensity of standard light was 1 c.p. throughout the descent

DIFFERENCE IN INTENSITY OF STANDARD AND VARIABLE LIGHTS (HEFNER UNITS)	NUMBER OF TRIALS	RIGHT CHOICES	WRONG CHOICES	WRONG ON RIGHT	WRONG ON LEFT	PER CENT OF ERROR
2.0	330	253	77	37	40	23.3
1.5	75	71	4	3	1	5.3
1.0	105	94	11	7	4	10.4
0.5	75	70	5	1	4	6.6
0.4	90	83	7	2	5	7.7
0.3	30	30	0	0	0	0.0
0.2	105	100	5	1	4	4.7
0.1	225	139	86	60	26	38.2

Position habit formed; returned to difference of 1 c.p.

1.0	235	110	25	21	4	18.5
0.5	75	65	10	4	6	13.3
0.4	270	196	74	51	23	27.4

Position habit formed; returned to difference of 1 c.p.

1.0	330	295	35	16	19	11.8
0.5	60	55	5	2	3	9.0
0.45	285	239	46	17	29	16.1
0.4	105	87	18	9	9	17.1
0.375	30	30	0	0	0	0.0
0.350	105	87	18	12	6	17.1
0.423	60	54	6	3	3	10.0
0.300	45	44	1	0	1	2.0
0.280	135	110	25	13	12	18.6
0.260	150	136	14	9	5	9.6
0.240	105	93	12	9	3	11.4
0.220	450	299	151	116	35	33.3

Position habit formed at this difference. Problem discontinued because of growing instability of habit of discrimination

Henceforth the steps in the reduction of the difference in the brightness of the two lights was made very small in order to make new problems less difficult than they had been in previous descents toward the threshold. Excepting several short time

lapses, the habit of going to the darker light was maintained in the third descent until a difference of 0.22 c.p., was reached. At this difference the habit became very unstable and eventually broke down completely. He was not able to make consecutively thirty perfect choices in 450 trials.

It would have been necessary to retrain him on an easier problem to have again established the habit of discrimination. But because of the increasing difficulty of maintaining the discrimination habit it was believed that the value of a fourth descent would be insufficient to justify further discrimination tests with this subject.

During the first descent toward the threshold, he seemed to have reached the approximate limit of discriminability at 0.1 c.p. The detailed records for the first descent show that this dog was able to discriminate a difference of 0.1 c.p., even though unable to make thirty consecutive errorless choices. In the first 20 consecutive choices he made only 20 per cent of error. In the first 60 choices he made 25 per cent of error. And in the first 90 tests the per cent of error was 27.7. This per cent of error closely approximates the criterion used by Yerkes¹³ as an index of the just perceivable difference. The increasing number of errors from the beginning of this problem is due to the gradual weakening of the discrimination habit, which broke down entirely soon after the first 90 trials.

From these results it seems safe to conclude that the male dog could discriminate a difference in intensity of illumination as low as 0.1 c.p. At this difference, however, discrimination is difficult and can be done only under exceedingly favorable conditions in which the habit of discrimination is very stable. It is not possible to state the threshold of discrimination as defined at the outset of this experiment on account of the occasional errors of discrimination which made it impossible to secure 30 consecutive errorless choices before the habit broke down. From the data at hand, however, it may be assumed that the threshold is near 0.1 c.p. with the intensity of the standard light at 1 c.p.

¹³ *The Dancing Mouse*, p. 123.

IV. COMPARATIVE STUDY OF LIGHT DISCRIMINATION

1. *Discrimination in man.* Three human subjects were given extensive tests in brightness discrimination under conditions identical with those observed in the testing of the dogs and with the intensity of the standard light at 1 c.p. Each subject discriminated readily a difference of 0.11 c.p. for thirty consecutive trials. Two of the subjects failed to make 30 perfect choices with a difference of 0.1 c.p. intensity during 150 trials. The other subject succeeded in reaching this standard of accuracy with a difference of 0.09 c.p., but failed (150 trials) at a difference of 0.08 c.p. In subsequent tests with a difference of 0.06 c.p. each subject made less than 20 per cent of error in 45 consecutive trials. One subject made, in 45 trials, only 17.7 per cent of error with a difference of 0.04 c.p.; with this difference, the per cent of error of the other subjects rose to approximately 35. From these results it is evident that the human subject can discriminate much smaller differences than the dogs could be trained to discriminate.

2. *Comparison of least brightness differences discriminated.* The so-called thresholds of visual discrimination that have been reported for animals are really only crude approximations of the true limits of just perceivable differences in illumination. As we have intimated heretofore, the usefulness of the discrimination method for the determination of the brightness threshold is dependent in large measure upon the stability and persistence of discrimination habits in the animals at times when differences in visual stimuli are so small that discrimination is difficult. Up to the present time the reported thresholds have not been adequately checked by other methods of experimentation. On this account we cannot definitely say whether the reported thresholds really represent the just perceptible difference in illumination or whether they merely denote the difference at which discrimination is sufficiently difficult to cause disruption of the discrimination habits.

At the present time we can make only rough comparisons of the least brightness differences discriminated by different

animals because of the difficulty of equating the differences in experimental procedure. Probably the most comparable results have been gotten by the use of the Yerkes-Watson type of light apparatus. Results gotten by this mode of presenting the brightness stimuli will be considered in the following comparison. The ratios of the intensity of illumination of the standard and the variable lights has been taken as the best available basis of comparison. The validity of this basis of comparison rests on the assumption that Weber's law holds for animals.¹⁴ In table 6 are given the conditions under which

TABLE 6
Conditions under which the thresholds of light discrimination were determined for man, the dog, the English sparrow, and the dancing mouse

SUBJECT	NUMBER OF TRIALS INDICATIVE OF DISCRIMINATION	PER CENT OF ACCURACY REQUIRED	INTENSITY OF STANDARD LIGHT	INTENSITY OF VARIABLE LIGHT
Human S, H, W*	30	100	c.p. 1.0	Greater than 1 c.p.
Human A, B, C†	30	100	0.09755	Both greater and less than 0.09755 c.p.
Dogs*	30	100	1.0	Greater than 1 c.p.
English sparrows†	30	100	0.09755	Both greater and less than 0.09755 c.p.
Dancing mouse‡	100	75	5.0	4.5 c.p.

* This study.

† Tugman, Eupha Foley. *Light Discrimination in the English Sparrow*, pp. 85-88.

‡ Yerkes, R. M. *The Dancing Mouse*.

the thresholds to be compared were obtained. In this table are indicated the number of correct trials and per cent of accuracy, taken as criteria of discrimination. It gives also the intensity of the standard light and states whether the intensity of the variable was greater or less than that of the standard.

Table 7 presents the ratios of the intensities of the standard and the variable lights as discriminated by six human subjects, two dogs, four English sparrows, and one dancing mouse.

¹⁴ Watson, J. B. *Animal Behavior*, p. 359.

As shown by the ratios, the threshold for man is the lowest. Owing to the use of a somewhat more lenient criterion for discrimination in the mouse the ratio for this animal is somewhat larger than it would have been according to the criterion used in obtaining the ratios for the other animals considered. If the criterion of Yerkes is applied to the results of subjects S, H, and

TABLE 7

Comparison of thresholds of discrimination

In this comparison the ratio of the intensities of the darker and the brighter lights is taken as the basis of comparison

GROUP	SUBJECT	RATIOS OF INTENSITIES OF LIGHTS (INTENSITY OF DARKER LIGHT: INTENSITY OF BRIGHTER LIGHT)
Man.....	S	9.17 : 10
	H	9.01 : 10
	W	9.01 : 10
	A	8.6 : 10
	B	9.1 : 10
Dog.....	C	8.6 : 10
	A	8.7 : 10
English sparrows.....	B	8.3 : 10
	Male IV	8.4 : 10
	Female V	6.5 : 10
	Male V	6.9 : 10*
Dancing mouse.....	Female VI	7.7 : 10
		9.0 : 10

* Died at this ratio.

W, their best discrimination records would be represented by the ratios 9.61: 10 for S and 9.43: 10 for H and W. This same criterion applied to the results of the dogs gave a ratio of 8.9: 10 for the female and 9:10 for the male. Similar ratios for the other human subjects and the sparrows are not available, but it is almost certain that they would be somewhat larger than those given in the foregoing table.

SUMMARY

Two dogs and three human subjects were trained in the discrimination of two light windows differing only in intensity of illumination. The chief facts revealed are as follows:

1. With the intensity of the standard light at 1 c.p. and the variable light slightly greater, the least differences at which 30 consecutive errorless discriminations were made by each subject are:

	C. P.	RATIO OF STANDARD TO VARIABLE
Female dog.....	0.14	8.7 : 10
Male dog.....	0.2	8.3 : 10
Human H and W.....	0.11	9.0 : 10
Human S.....	0.09	9.17 : 10

2. The lowest differences at which clear evidence of discrimination was obtained for each subject are:

	C. P.	PER CENT OF ERRORS	NUMBER OF TRIALS
Female dog.....	0.12	26.5	75
Male dog.....	0.10	27.7	90
Human H and W.....	0.06	20.0	45
Human S.....	0.04	17.7	45

3. The human subjects were able to discriminate differences lower than those that animals have been trained to discriminate. The dogs discriminated differences lower than those discriminated by the English sparrow (Tugman) and as low as the best record reported (Yerkes) for the discrimination of the dancing mouse.

REFERENCES

- (1) COLVIN, S. S., AND BURFORD, C. C.: The color perception of three dogs, a cat, and a squirrel. Psychol. Monog., 1909, ix, no. 44.
- (2) GATES, ELMER: The science of mentation. Monist, 1895.
- (3) GRABER, VITUS: Grundlinien zur Erforschung des Helligkeits und Farbensinnes des Tiere. Prag., 1884.
- (4) HIMSTEDT, F., AND NAGEL, W. A.: Versuche über die Reizwirkung verschiedener Strahlenarten auf Menschen und Tieraugen. Freiburg, Festschr. d. Univ., 1902, p. 259.

- (5) JOHNSON, H. M.: Visual pattern discrimination in the vertebrates. I, II, Jour. Animal Behav., 1914, iv.
- (6) ORBELLI, L. A.: Réflexes conditionnels du côté de l'oeil chez le chien. Arch. des Sciences Biologiques, 1909, xv, nos. 1 and 2.
- (7) SMITH, E. M.: Some observations concerning color vision in dogs. Brit. Jour. Psychol., 1912, v.
- (8) STINE, WILBUR M.: Photometrical measurements.
- (9) TUGMAN, EUPHA FOLEY: Light discrimination in the English sparrow. Jour. Animal Behav., 1914, iv.
- (10) WATSON, J. B.: Some experiments bearing upon color vision in monkeys. Jour. Comp. Neur. and Psychol., 1909, xix. Jour. Animal Behavior. Henry Holt & Co., 1914.
- (11) YERKES, R. M., AND WATSON, J. B.: Methods of studying vision in animals. Behav. Monog., Ser. no. 2.
- (12) YERKES, R. M.: The dancing mouse. New York, Macmillan, 1907.