PRELIMINARIES TO A STUDY OF COLOR VISION IN THE RING-DOVE *TURTUR RISORIUS*[1]

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At the present moment a thorough study of the visual reactions of a few types of birds and mammals is highly desirable. This paper presents an account of observations on the reactions of the ring-dove in the Watson-Yerkes color vision apparatus. The ring-dove was chosen as a subject because of its easy adaptation to laboratory conditions and its convenient size. It was hoped that it might prove an ideal bird for the intensive study of vision.

As a preparation for the study of color discrimination, the limits of the spectrum, and the stimulating values of various wave-lengths, observations were first made on the response of the bird to achromatic stimuli. The apparatus used throughout the preliminary work here reported was the Watson-Yerkes spectral color vision device, as described in volume one of the Behavior Monographs.[2] A Bausch and Lomb automatic arc lamp was used as a source of light, and a selenium cell, as described in the monograph (pp. 79-81) served as a means of measuring the energy of the stimuli employed. For the simple reaction-box shown as W in figure 7 of the monograph, the box represented in figure 1 of this paper was substituted, and instead of having two reflecting surfaces, M and L of figure 7 above referred to, fixed on the experiment-box and moving laterally with it, three reflecting surfaces were employed. These remained fixed while the experiment-box moved sufficiently to reverse the position of the two photic stimuli.

[1] This work has been made possible by a grant from the Bache Fund of the National Academy of Arts and Sciences, which enabled the author to complete the construction of a spectral apparatus and install a selenium cell outfit to measure chromatic stimuli. Grateful acknowledgment is made to the trustees of the Fund and to the Committee in charge, for the facilitation of this research.

[2] Yerkes, Robert M., and Watson, John B. Methods of studying vision in animals. *Behavior Monographs*, 1911, vol. 1.

The general apparatus need not be redescribed in detail. The reader who is unfamiliar with it is referred to the above-mentioned monograph and to Watson's more recent book.[3] In brief, it consists of a source of light which, by means of a system of lenses, prisms, and slits, is made to supply chromatic stimuli in any desired quality or intensity. Two stimuli are presented to the subject simultaneously. The position of these stimuli may be reversed at the will of the experimenter. The subject is required to distinguish the stimuli and react differently to the two.

Assuming, now, that the reader has a general knowledge of the mechanism by which the chromatic stimuli are obtained, controlled, and measured, we may consider our method of procedure in its relations to the reaction-box of figure 1. This consists of an entrance chamber (A) in which, at the beginning of a series of observations, the subject is placed by the experimenter, and from which it passes, when the door (D) is raised, into compartment B, which may be designated the discrimination compartment. A sliding partition (M) enables the experimenter to avoid delay because of the unwillingness of the subject to enter B, for by raising the door (D) and drawing M slowly and steadily backward toward the rear of compartment A, the subject may, without disturbance, be compelled to enter the discrimination compartment. Once in B, the subject faces the two stimuli S, S. These are presented either with or without general overhead illumination, and they appear as illuminated surfaces, either chromatic or achromatic, 7 cm. long by 1.8 cm. wide. These two stimuli are separated by the partition P, of figure 1.

On the floor of each stimulus-box, E, are electrodes by means of which electric shocks may be given as punishment for failures to distinguish and properly to react to the two stimuli. The doors F, F, leading from the stimulus compartments into the alleys G, G, may be raised by the experimenter by means of the cords shown in the figure. When the subject enters the compartment which contains the stimulus selected by the experimenter as the positive stimulus, the appropriate door F is immediately raised, the slide-door, H, of the same side opened, and the subject thus permitted to pass by way of the alley G,

[3] Watson, J. B. Behavior. New York, 1914, p. 70.

back to the starting point at A, where is it allowed to feed for a definite interval. In case, however, the subject enters the other compartment, it is not allowed to pass into the alley, but instead, either with or without the use of the electric shock, according to the experimenter's previous decision, it is required to retrace its steps and again attempt to distinguish the stim-

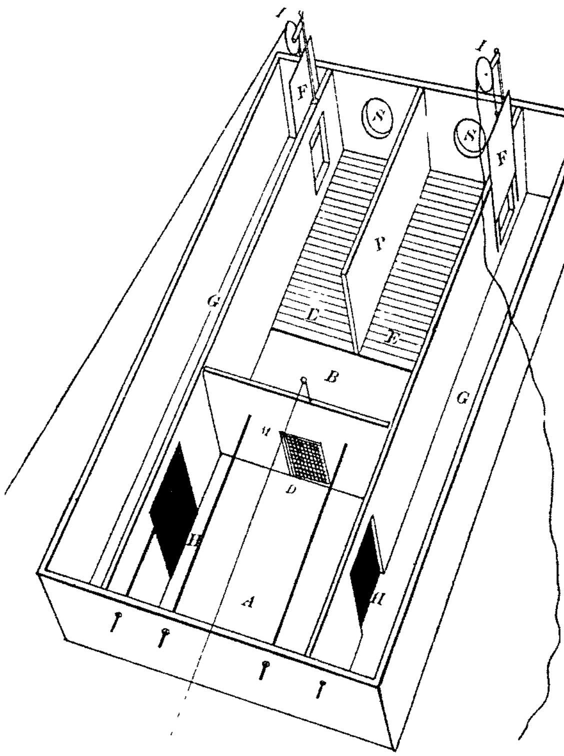

FIG. 1. Reaction-box for Ring-doves. A, entrance chamber; B, discrimination compartment; D, screen-door; M, sliding partition moving in A and B; E, E, stimulus compartments; P, partition between E and E; F, F, doors between stimulus compartments and alleys G, G,, H, H, slide-doors between G and A; I, I, pulleys for cords attached to F, F, S, S, stimulus apertures.

ulus which demands positive reaction from that which demands negative reaction.

In the case of the observations about to be described, achromatic stimuli were obtained by placing a two candle power carbon incandescent lamp 86 cm. from the stimulus area. Thus, the one of the stimulus areas presented to the subject was always illuminated, whereas the other was entirely unilluminated, except as general illumination was employed in the experiments. Naturally, as the experiment-box was shifted from side to side, the more intense achromatic stimulus was presented now in the stimulus compartment on the right of the subject, now in the one on the left.

The writer is convinced that wherever possible the interference of the experimenter in the course of an animal's reaction should be obviated by the use of automatic or subject-actuated devices. It was not feasible, however, in the present investigation, to introduce such devices,—consequently the use of the slide-doors, as shown in figure 1. These, it should be stated, proved surprisingly satisfactory in the case of the ring-dove, which is easily startled and which would not react well in a subject-actuated apparatus unless everything could be made to work steadily, quietly, and fairly slowly. It is, however, beyond question that our efforts in studies of behavior should be to eliminate, as far as possible, the necessity, during the course of reaction, of movements by the experimenter which tend to modify the behavior of the subject. It has repeatedly appeared that even the experienced investigator is liable, unconsciously, to supply cues to his subject which facilitate proper reaction, or even serve as the sole basis for what appears to be discrimination.

The birds used for the present work were obtained from a Boston dealer. All that could be learned about them was that they were young We are therefore under the disadvantage of being unable to give a satisfactory description. It is obviously desirable in all such investigations that the origin and exact age, as well as the sex and history of each subject, should be known. But this is somewhat less essential, it must be admitted, in the case of preliminary observations than in that of continuation-work. Four birds were used. Of these, two, supplied as male and female by the dealer, in reality both males, appear as numbers 1 and 2 in this report. They were used over a period of several weeks by Mr. A. M. Eisenberg. The others appear as number 3, a female, and number 4, a male. During a period of five months these birds were used in the visual experiment by the writer. The results obtained with numbers 1 and 2 will be presented only in contrast with those of numbers 3 and 4, since the conditions of use varied somewhat, and the experiments conducted by Mr. Eisenberg were not carried so far as those of the writer. The descriptions of general behavior in this paper will be based almost wholly upon the observations made on doves 3 and 4.

At the outset, it was assumed that the ring-dove would react satisfactorily in the discrimination apparatus, that it would exhibit a fair degree of docility, breed rapidly in captivity, be easy to handle, and endure close confinement well. It must be admitted that these assumptions have not all been justified, for the birds did not quickly adapt themselves to the experimental situations, and in docility they rank low. Indeed, their slowness in acquiring the discrimination habit demanded in this work was a great surprise to the writer. He is now somewhat uncertain as to whether it is desirable to attempt an intensive study of visual response with a subject which demands such a large amount of training.

Work was initiated by feeding the birds in the entrance chamber of the experiment-box, with all of the doors of the box open so that the subject might wander about at will. This was continued for a week, with the occasional variation of opening and closing the doors as the bird passed from compartment to compartment, so that it might become accustomed to the operating of the simple mechanisms and learn the route from the entrance chamber, by way of the stimulus chamber, back to the starting point.

During the second week of the preliminary observations, the birds were sufficiently tame and accustomed to the apparatus to work fairly well. They were regularly each morning required to make the trip through the apparatus three or four times, and they were rewarded for so doing with food. It was discovered that they would not make the trip quickly unless they were very hungry, and even in that condition their attention to the situation was very variable, and they were so easily distracted by slight noises or jars that the whole process was a very tedious one. It thus became apparent that unless an additional motive for discrimination and progress through the experiment-box could be discovered, the work would be most tedious. Consequently, at the beginning of the third week, the electric shock was introduced as a means of compelling attention to the visual stimuli and of encouraging careful comparison and appropriate reaction. Even from the start, the electric stimulus served this purpose admirably. It at once rendered the birds more alert, careful, attentive, and active. The writer's notes record, " In two weeks the doves apparently have learned nothing, but to-day as the result of four trials with electrical stimulation, each seemed to attempt to discriminate between the light and the dark chambers.

It was decided, on the basis of the preliminary observations, that the doves should be required to choose the lighter rather than the darker of the two compartments.

Number 3, the female, was at the outset much less wild and more timid than number 4, the male. It was much easier for the experimenter to catch her in the living-cage than to catch him, but when in the experiment-box, she was very much more disturbed, excitable, and liable to discouragement than he. By contrast, then, the female may be described as tame and timid. the male as wild and bold. But it should be added that neither bird was sufficiently wild to be difficult to handle.

On February 28th, 1914, systematic, regular experiments were begun, with the use of both food and the electric shock. Both birds worked well in the six trials which were given. Only one bird was used at a time, and it was given its trials in succession, with from one-half to one minute interval for feeding between choices. In comment on this day's reactions, the writer's notes state that " The use of the electric shock discreetly and infrequently has transformed the birds from time-wasting and careless subjects to active, alert, constantly moving reactors. This modification of method evidently means a saving of an immense amount of time to the experimenter. It enables him to command the attention of his subject instead of having to beg for it by the offering of food. Food, however, is serving an excellent purpose in the work, for each bird comes to its task hungry and usually feeds between trials."

On March the 2nd, the number of trials for each bird was increased to ten, and it was subsequently found that as many as fifteen or even twenty trials could be given in succession without overfatiguing the subjects and with excellent results.

Table 1 presents two sample detailed records of the daily trials from the writer's note-book. The first portion of the table gives the results of an early series of ten choices, those of March 4th. The remainder of the table presents, by contrast, the results of a later series of fifteen trials in which the birds were practically perfect in their discrimination. This series was given on April 19th. The table indicates, in the first column, the position of the positive stimulus, that is the stimulus indicative of the chamber to be entered. In the second column, the letters R and W designate, respectively, correct and incorrect choices.

TABLE 1

EXAMPLES OF DETAILED DAILY RECORDS

March 4, 1914, 10.10 A M. With general illumination. Stimulus-lamp 86 cm from stimulus area. Coil at 1 cm for female and 2 cm. for male.

		Female, No 3		Male, No. 4	
Trial	Positive stimulus	Reaction	Remarks	Reaction	Remarks
1	Left	W	Shocked?	W	Shocked?
2	"	W	"	W	"
3	"	W	"	W	Shocked
4	Right	R	Direct	W	"
5	Left	W	Shocked?	R	Discrimination
6	Right	R		R	Anxious
7	"	W		R	"
8	"	W	Shocked	R	Eager
9	Left	R		W	No shock
10	Right	W		W	Shock
Summary.		4 R:6 R		4 R·6 W	

April 19, 1914, 9:50 A. M. With general illumination. Stimulus-lamp 126 cm. from stimulus area. Coil at 2 cm. for both

		Female, No 3		Male, No. 4	
1	Left	R	Near-mistake	R	Exc. disc
2	Right	R	Direct	R	
3	"	R	"	R	
4	"	R	"	R	
5	"	R	"	R	
6	Left	R	"	R	
7	"	R	Good disc.	R	
8	"	R	"	R	
9	"	R	Near-mistake	R	Careful
10	Right	R	Eager	R	
11	Left	R		R	
12	Right	R	Direct	R	
13	"	R	"	R	
14	Left	R	Near-mistake	R	
15	"	W	Careless	R	
Summary:		14 R:1 W		15 R:0 W	

TABLE 2

SUMMARY OF RESULTS OF TRAINING IN LIGHT-DARK DISCRIMINATION. ELECTRICALLY ILLUMINATED AREA VERSUS UNILLUMINATED AREA. ELECTRIC SHOCK USED AS PUNISHMENT.

Dove Number 3, ♀				Dove Number 4, ♂			
Date	Conditions	Right	Wrong	Date	Conditions	Right	Wrong
Feb. 28	Gen. ill., elect. stim....	3	3	Feb. 28	Gen. ill., elect. stim . .	4	2
Mar. 1	No gen. ill., elect. stim.	3	3	Mar. 1	No gen. ill., elect. stim.	4	2
" 2	" " " " "	8	2	" 2	" " " " "	5	5
" 3	Mixed illum., " "	9	1	" 3	Mixed illum., " "	5	5
" 4	Gen. illum., " "	4	6	" 4	Gen. illum., " "	4	6
" 5	" " " "	6	4	" 5	" " " "	6	4
" 6	" " " "	4	6	" 6	" " " "	7	3
" 7	" " " "	4	6	" 7	" " " "	6	4
" 8	" " " "	6	4	" 8	" " " "	4	6
" 9	" " " "	3	7	" 9	" " " "	5	5
" 10	" " " "	6	4	" 10	" " " "	7	3
" 11	" " " "	5	5	" 11	" " " "	4	6
" 12	Mixed gen. ill. " "	4	6	" 12	Mixed gen. ill. " "	9	1
" 13	" " " "	6	4	" 13	" " " "	8	2
" 14	Gen. illum., " "	5	5	" 14	Gen. illum., " "	8	2
" 15	" " " "	3	7	" 15	" " " "	6	4
" 16	No. gen. ill., " "	4	6	" 16	No gen. ill., " "	6	4
" 17	Gen. illum., " "	5	5	" 17	Gen. illum., " "	5	5
" 26	" " " "	3	7	" 26	" " " "	5	5
" 27	" " " "	9	1	" 27	" " " "	5	5
" 28	" " " "	4	6	" 28	" " " "	4	6
" 29	" " " "	6	4	" 29	" " " "	5	5
" 30	" " " "	4	6	" 30	" " " "	5	5
" 31	" " " "	4	6	" 31	" " " "	5	5
Apr. 1	" " " "	11	4	Apr. 1	" " " "	5	10
" 2	" " " "	9	6	" 2	" " " "	5	10
" 3	" " " "	8	7	" 3	" " " "	13	2
" 4	" " " "	9	6	" 4	" " " "	9	6
" 5	" " " "	8	7	" 5	" " " "	8	7
" 6	" " " "	12	3	" 6	" " " "	10	5
" 7	" " " "	9	6	" 7	" " " "	9	6
" 8	" " " "	11	4	" 8	" " " "	11	4
" 12	" " " "	11	4	" 12	" " " "	14	1
" 13	" " " "	13	2	" 13	" " " "	14	1
" 14	" " " "	14	1	" 14	" " " "	13	2
" 15	" " " "	10	5	" 15	" " " "	13	2
" 16	" " " "	12	3	" 16	" " " "	14	1
" 17	Stim. less, " "	11	4	" 17	Stim. less, " "	15	0
" 18	" " " "	13	2	" 18	" " " "	14	1
" 19	" " " "	14	1	" 19	" " " "	15	0
" 20	" " " "	12	3	" 20	" " " "	14	1

The general results of the several series of reactions required for doves number 3 and number 4 appear in table 2, under their appropriate dates. A brief statement is given in the second column of the table of the important conditions of reaction. It is stated, for example, whether general illumination was used

TABLE 3

SUMMARY OF RESULTS OF TRAINING IN LIGHT-DARK DISCRIMINATION. ELECTRICALLY ILLUMINATED AREA VERSUS UNILLUMINATED AREA. ELECTRIC SHOCK NOT USED

Dove Number 1, ♂				Dove Number 2, ♂			
Date	Conditions	Right	Wrong	Date	Conditions	Right	Wrong
Mar. 2	Gen. illum.	3	7	Mar. 3	Gen. illum.	2	3
" 3	" "	5	5	" 4	" "	2	3
" 4	" "	4	6	" 7	" "	2	3
" 7	" "	1	4	" 9	" "	2	3
" 9	" "	2	3	" 10	" "	2	3
" 10	" "	0	5	" 11	" "	2	3
" 11	" "	3	2	" 12	" "	2	3
" 12	" "	3	2	" 13	" "	0	5
" 13	" "	3	2	" 14	" "	2	3
" 14	" "	4	1	" 16	" "	2	3
" 16	" "	0	5	" 17	No gen. illum	1	4
" 17	No gen. illum	1	4	" 18	" " "	2	3
" 18	" " "	1	4	" 19	" " "	2	3
" 19	" " "	1	4	" 20	" " "	1	4
" 20	" " "	2	3	" 21	" " "	2	3
" 21	" " "	1	4	" 23	No gen. ill., elect. stim.	1	4
" 23	No gen. ill., elect. stim.	2	3	" 24	" " " " "	2	3
" 24	" " " " "	2	3	" 25	" " " " "	1	4
" 25	" " " " "	3	2	" 26	" " " " "	5	5
" 26	" " " " "	2	3	" 27	" " " " "	4	6
" 27	" " " " "	2	3	" 28	" " " " "	4	6
" 28	" " " " "	3	2	" 30	" " " " "	4	6
" 30	No gen. illum.	4	6	" 31	" " " " "	5	5
" 31	" " "	5	5	Apr. 1	Gen. illum.	5	5
Apr. 1	Gen. illum.	2	8	" 2	" "	5	5
" 2	" "	6	4	" 3	" "	6	4
" 3	" "	1	9	" 4	" "	7	3
" 4	" "	4	6	" 6	" "	4	6
" 6	" "	8	2	" 8	" "	6	4
" 8	" "	5	5	" 9	" "	4	6
" 9	" "	5	5	" 10	" "	4	6
" 10	" "	2	8	" 11	" "	5	5
" 11	" "	5	5	" 13	" "	6	4
" 13	" "	5	5	" 14	" "	5	5
" 14	" "	4	6	" 16	" "	5	5
" 17	" "	7	3	" 17	" "	5	5
" 18	" "	5	5	" 18	" "	7	3
" 20	" "	2	8	" 20	* "	4	6
" 21	" "	3	7	" 21	" "	7	3
" 23	" "	10	0	" 23	" "	3	7
" 24	" "	6	4	" 24	" "	10	0
" 25	" "	1	9	" 25	" "	5	5
" 27	" "	10	0	" 27	" "	9	1
" 28	" "	10	0	" 28	" "	6	4
" 29	" "	10	0	" 29	" "	9	1
" 30	" "	10	0	" 30	" "	5	5
May 9	" "	6	4	May 1	" "	6	4
" 11	" "	9	1	" 2	" "	10	0
" 14	" "	6	4	" 2	" "	10	0
				" 4	" "	10	0
				" 9	" "	9	1
				" 11	" "	8	2
				" 14	" "	5	5

or not, and it is indicated that in a few series of observations the conditions of illumination were mixed, that is, for some of the reactions general illumination was employed, whereas in others it was lacking Throughout the regular experiments the electric stimulus was employed. On April 17th, as is indicated, the intensity of the visual stimulus was lessened, thus diminishing the difference in the stimuli to be distinguished.

Table 3 presents the comparable results for doves number 1 and number 2. The chief difference in the conditions for these results and those obtained with doves numbers 3 and 4 is the absence of the electric stimulus in the case of the former. With the exception of one week, March 23rd to March 28th, Mr. Eisenberg trained number 1 and number 2 to achromatic discrimination on the basis of food as a reward without the use of the electric shock as punishment for mistakes. His results, therefore, may be compared with those of the writer, with a view to discovering the value of punishment as contrasted with reward in this experiment with ring-doves.

Such comparison indicates, in the first place, that it is possible to make a larger number of observations per series with punishment than without it. Thus, the writer by the aid of the electric stimulus was able to make ten, fifteen or even twenty observations per series. Whereas, Mr. Eisenberg, without the electric stimulus, could not satisfactorily make more than ten observations, and during a considerable portion of the training he made only five. Second, the time required for the work varied much more widely when punishment was not used than when it was used. As appears from tables 2 and 3, all of the doves acquired the ability to discriminate with a reasonable degree of certainty, and to react appropriately The course of habit formation in case of each of the four subjects is surprising. Instead of being steady, regular, and fairly rapid, as the writer had anticipated, it proved to be irregular and extremely slow. One day the experimenter would feel confident that his subjects were acquiring the habit, and the next day he would find them utterly unable to react properly.

In table 4 the choices are presented by groups of fifty, and the course of habit formation is indicated with the daily variations eliminated. This table shows that as the result of three hundred trials, no one of the four doves had acquired the ability

TABLE 4

REACTIONS IN LIGHT-DARK TRAINING GROUPED IN FIFTIES TO SHOW SLOWNESS OF IMPROVEMENT AND IRREGULARITIES

Trials	Dove 1, ♂		Dove 2, ♂		Dove 3, ♀		Dove 4, ♂	
	Right	Wrong	Right	Wrong	Right	Wrong	Right	Wrong
1–50	18	32	18	32	32	18	27	23
51–100	18	32	20	30	23	27	29	21
101–150	22	28	21	29	23	27	35	15
151–200	23	27	28	22	25	25	25	25
201–250	20	30	25	25	27	23	22	28
251–300	25	25	26	24	30	20	29	21
301–350	37	13	36	14	34	16	34	16
351–400	36	9	41	9	41	9	46	4
401–450			27	8	38	12	47	3
451–500					30	5	33	2

to react properly. Between the three hundredth and the four hundredth trials, all of them, however, showed marked improvement. Were it not that two experimenters were involved and the conditions of observation thoroughly controlled, it might fairly be suspected that the doves finally discovered some other basis for reaction than the difference in the intensity of illumination. We are convinced, however, that this was not the case and that the results satisfactorily prove that the ring-dove is extremely slow, under the conditions described, in learning to react appropriately to achromatic stimuli, even though they differ very markedly. It must be admitted, however, that there are certain features in table 3 which are puzzling. Number 1 discriminated perfectly on April 23rd, and number 2 on April 24th, whereas on both the preceding and the following days they did poorly. This suggests to the writer that they had happened upon some means of choosing other than that intended by the experimenter.

From a careful comparison of the data of tables 2, 3, and 4, it is clear that by the use of the electric stimulus, it is possible to develop a visual discrimination habit in the dove much more quickly, and consequently with less labor, than by the employment of the food getting desire alone

All of the foregoing observations are merely preparatory to the work with chromatic stimuli. It therefore seems unnecessary to burden the reader with further details of conditions or results, except possibly with respect to the general illumination and its relation to the reactions. In some of the series, general illumination was not employed, and it was naturally apparent that the doves could distinguish the stimuli much more easily than when the surroundings were illuminated. It was deemed desirable to use general illumination in order to guard against choice on the basis of the visibility of the sides and floor of the stimulus chambers, for naturally enough, this differed greatly in the light and the dark chambers in the absence of general illumination. On the whole, it seemed very much more satisfactory to conduct experiments in the general illumination produced by a two candle power frosted carbon incandescent lamp, at a distance of 110 cm. above the center of the partition beween the stimulus chambers.

As an aid to rapid reaction, the alleys of the experiment-box were kept dark except at the moment of entrance of the dove. In each alley was placed a low-power lamp which could be turned on the instant the door F was raised, and turned off the instant the door H was opened. This served to induce the dove to enter the alley-way and to hasten through it to the food-box. After a few daily series, the birds made the trip quickly and voluntarily, seldom loitering in the passageways and usually passing from entrance chamber to discrimination chamber rapidly.

The food placed in the entrance chamber as a motive for return to that portion of the experiment-box was milk-soaked bread, with a small quantity of cracked corn added. During a large portion of the series, the birds ate little, unless they were practically deprived of food while in the living-cage. It is thus fair to say that the process of habit formation in the case of doves 3 and 4 depended almost solely upon punishment, whereas the process in the case of birds 1 and 2 depended solely upon reward.

As in the writer's previous use of punishment, the induced current was used by means of a Porter inductorium with a number 6 Columbia dry cell as source of current. In the early experiments, no attempt was made to keep the feet of the birds moist, and as a consequence, the secondary coil had to be placed well over the primary. Its position was varied somewhat from day to day, but in general it was placed at 1 cm. for the female and at 3 cm. for the male. This, of course, means that the male responded to a very much weaker electric stimulus than did the female, but it is probable that this indicates not so much a difference in sensitiveness to the stimulus as the result of difference in weight, for the male bird was much heavier than the female. During March it was found difficult to get satisfactory responses, even when the maximum current was used, and the experimenter finally hit upon the device of placing a square piece of moist blotting paper before the food-box in the entrance chamber. This was found to yield very satisfactory results. The secondary now had to be set at 2 cm. for the female and 2½ for the male. The settings proved satisfactory throughout the remainder of the work, and whereas previously the responses to the electric stimulus had varied extremely, they subsequently were very constant.

RESULTS WITH CHROMATIC STIMULI

Doves 3 and 4, having been trained to practically perfect discrimination of a bright area from a dark area of the same size, were tested for preference of spectral red and green. The value of the red stimulus was 626 to 640$\mu\mu$, while that of the green was 498 to 510$\mu\mu$. In energy, as measured by the selenium cell, the red stood slightly above the green, but they were so nearly the same that it seemed needless to attempt to equate them more closely for these preliminary experiments.

Table 5 presents in summary the results of the chromatic reactions of doves 3 and 4. From this table it appears that on April 21st, when given an opportunity to choose either the red or the green chamber, without punishment, number 3 chose the one as often as the other, whereas number 4 chose the red eight times, the green twice. On April 22nd, in the absence of general illumination and with a period of two minutes for darkness adaptation before the series was commenced, the results were entirely different, for number 3 selected the green nine times out of ten, while number 4 chose it five times out of ten. On the following day, the original conditions of April 21st were reinstated and the responses were similar to those of that date. On April 28th, by the elimination of general illumination, darkness adaptation was effected, and the results again, as on April 22nd, favored the green

TABLE 5

RESULTS OF EXPERIMENTS WITH CHROMATIC STIMULI

Dove Number 3, ♀				Dove Number 4, ♂			
Date	Conditions	Red	Green	Date	Conditions	Red	Green
Apr. 21	Preference for red or green	5	5	Apr. 21	Preference for red or green	8	2
“ 22	“ “ “ (darkness adaptation)	1	9	“ 22	“ “ “ (darkness adaptation)	5	5
“ 23	“ “ “ (gen. illum.)	3	7	“ 23	“ “ “ (gen. illum.)	7	3
“ 28	“ “ “ (no gen. illum.)	4	6	“ 28	“ “ “ (no gen. illum.)	5	5
Apr. 29	Red-black training	11	9	Apr. 29	Red-black training	18	2
“ 30	“ “	16	4	“ 30	“ “	12	8
May 1	“ “	13	7	May 1	“ “	18	2
“ 2	“ “	13	7	“ 2	“ “	19	1
“ 3	“ “	10	10	“ 3	“ “	20	0
“ 4	“ “	17	3	“ 4	“ “	20	0
“ 5	“ “	18	2	“ 5	“ “	17	3
“ 6	“ “	17	3	“ 6	“ “	19	1
“ 7	“ “	19	1	“ 7	“ “	19	1
“ 8	“ “	18	2	“ 8	“ “	17	3
May 9	Red-green training	14	6	May 9	Red-green training	16	4
“ 10	“ “	10	10	“ 10	“ “	20	0
“ 11	“ “	10	10	“ 11	“ “	15	5
“ 12	“ “	13	7	“ 12	“ “	16	4
“ 13	“ “	15	5	“ 13	“ “	15	5
“ 14	“ “	13	7	“ 14	“ “	13	7
“ 15	“ “	14	6	“ 15	“ “	17	3
“ 16	“ “	14	6	“ 16	“ “	13	7
“ 17	“ “	14	6	“ 17	“ “	16	4
“ 18	“ “	13	7	“ 18	“ “	15	5
“ 19	“ “	16	4	“ 19	“ “	18	2
“ 20	“ “	16	4	“ 20	“ “	18	2
“ 21	“ “	15	5	“ 21	“ “	19	1
“ 22	“ “	17	3	“ 22	“ “	19	1
“ 23	“ “	14	6	“ 23	“ “	14	6
“ 24	“ “	14	6	“ 24	“ “	16	4
“ 25	“ “	18	2	“ 25	“ “	17	3
“ 26	“ “	18	2	“ 26	“ “	18	2
“ 27	“ “	20	0	“ 27	“ “	18	2
“ 28	“ “	20	0	“ 28	“ “	20	0

From these four series of ten reactions with doves numbers 3 and 4, it may be inferred that under the condition of general illumination in which these doves had been trained to distinguish the light stimulus patch from the dark and to react positively to the lighter of the two, the spectral red and green stimuli appeared of about the same intensity to the female dove, whereas to the male, the red appeared the more intense. One naturally infers that both birds, as a result of their previous training, would go to the stimulus patch which appeared the lighter of the two, supposing that an appreciable difference existed. The series of observations on April 22nd and 28th with darkness adaptation indicate that green appeared considerably lighter for both birds than without adaptation Green was chosen more frequently by number 3 than by number 4, apparently because the two stimuli were of more nearly the same value in general illumination for this bird than for the male.

From these few observations, and naturally only a few observations could be made of preference, we may conclude that spectral red and green stimuli of approximately the same energy values did not appear markedly different to the female dove in general illumination, whereas without general illumination the green seemed the more intense For the male, on the contrary, the red seemed somewhat more intense than the green, and darkness adaptation rendered the two of practically the same intensity.

Hess[4] has already demonstrated the Purkinje phenomenon in chickens and doves, by a method radically different from that of the writer, while Lashley[5] has more recently demonstrated it in the game bantam by the method of this investigation There seems to be no reason for doubting that the observations described above also constitute a satisfactory demonstration of the modification of stimulating value by adaptation

A series of observations was now instituted, beginning on April 29th, on the development of the ability to distinguish red from black and of the habit of reacting positively to red and negatively to black Supposing that red appeared light and black dark, it would seem that both doves, merely as the result of their light-dark training with colorless stimuli, should select red uniformly and avoid the black The results, however, as they appear in table 5, do not wholly justify this expectation.

[4] Hess, C. Untersuchungen über das Sehen und uber die Pupillenreaction von Tag- und Nachtvogeln. *Archiv. fur Augenheilkunde*, 1908, Bd. 59, S 143
————. Vergleichende Physiologie des Gesichtssinnes. Jena, 1912, Bd. 4, S. 9.

[5] Watson, J. B. Behavior. New York, 1914, p. 350.

Instead, they seem to indicate that for the female dove, the red was so dark that it tended to be confused with the black, or at least was not accepted as the equivalent of the light area which the bird had previously learned to choose.

In this red-black training, it was possible to give each dove twenty trials in succession. As a result of one hundred and forty trials, number 3 was reacting properly ninety per cent of the time. Curiously enough, the male, number 4, chose the red eighteen times out of twenty in his first series, and showed throughout his reactions, in the red-black training, ability to respond to these two stimuli much as he had to the light and dark achromatic stimuli. This is, of course, wholly in agreement with the results of the preference tests, which clearly indicated that the red stimulus for some reason possessed a higher stimulating value for the male than for the female.

It is, of course, impossible to say, on the basis of the red-black results, that either bird responded to the chromatic difference instead of to the intensity difference of the stimuli. It is doubtless safer to assume that the latter alone was the basis of choice.

Beginning on May 9th both doves were presented with the red and green stimuli which on April 21st had been offered as a basis for preference reactions, with the difference that now they were required to choose the red and to avoid the green on penalty of electric stimulation. Again, each daily series consisted of twenty successive trials The female exhibited, at first, slight ability to distinguish the two stimuli and to respond appropriately, but after three hundred and eighty trials, she was reacting perfectly. The male, on the contrary, reacted perfectly even from the first, his second series of twenty trials including no mistakes It is thus fairly clear that he responded to the intensity difference of the two chromatic stimuli, and it seems wholly probable, in view of the gradual development of the habit, that she also acquired the ability to respond to the same difference.

From these preliminary observations, it seems safe to conclude that for the ring-dove a red and a green from the spectrum of the carbon arc, of the wave lengths designated above, and of approximately the same energy, as measured by the selenium cell, are sufficiently unlike in stimulating value to be readily distinguished by certain individuals and with difficulty by others. The particular results in hand suggest that the red has a higher stimulating value for the male than for the female.

The next step in the experiment would naturally enough have been observation of the responses of the subjects to varied energy values (intensities) of the two chromatic stimuli. Unfortunately, the investigation had to terminate at the end of May and the laborious preparation for these final observations was unavoidably wasted. The writer had fully expected and hoped, within the period of six months at his disposal when the investigation was undertaken, to ascertain whether the ring-dove can distinguish a red from a green stimulus throughout a wide range of energy or intensity values. This he did not succeed in doing, and consequently this report must be entitled "Preliminaries to a study of color vision in the ring-dove."

The principal conclusions which may safely be drawn from these observations have been suggested in the course of the presentation, but by way of summary and review, they may be enumerated here.

1. It is fairly obvious that the ring-dove is not sufficiently docile to be an ideal subject for the study of color vision by means of the method which Watson and I have developed.

2 It is indicated that the value of a certain red and a certain green may be very different for two ring-doves, and it is possible that this difference is correlated with sex, the red having a higher stimulating value for the male than for the female.

3. As has already been demonstrated by the writer in the case of a number of animals, the use of the electric stimulus as a means of compelling attention to an experimental situation and of promoting habit formation is desirable in work with the ring-dove.

4. Ring-doves differ markedly in temperament. The pair used by the writer throughout this work presented differences which must be considered if one is to understand the results. To begin with, the male was somewhat wild, but at the same time fairly bold, whereas the female was tamer but more timid. Because of this contrast in timidity, the male almost from the start proved the better subject. He was not so easily disturbed or distracted, reacted therefore more steadily, and chose more certainly. With constant handling he became quite as tame as

the female and lost almost entirely his timidity in the apparatus. She, however, continued to be rather timid throughout the several months of work, although she was perfectly tame. The differences in the nature of the reactions, as recorded in the experimenter's record-book, can be appreciated only in the light of these temperamental facts.

The sex contrasts indicated in the above paragraphs one dare not emphasize very strongly on the basis of observations on two individuals, but they at least suggest the desirability of further study of the sexes. It is the writer's opinion that they agree sufficiently closely with the results obtained in the case of other animals to justify their provisional acceptance

As has been repeatedly noted with other animals, there are good and bad days in experimental work with ring-doves,—days which are good or bad, not, so far as one may tell, because of variation in the experimenter or his manipulation of the apparatus, but chiefly because of variations in the condition of the subjects. The experiments described in this paper were made at about the same hour each morning, and it was quite impossible for the experimenter to predict the outcome of a series in the light of previous series, for the attention of the doves to the situation seemed to vary independently of any conditions or group of conditions which the experimenter could take into account. There are animals which can be relied upon to work steadily and fairly predictably. The ring-dove is not one of them.

The writer has been led to reflect, because of the outcome of this series of observations, on the possible relation of the simplicity of the experimental situation to the results. He was compelled to devote several weeks to the establishment of a simple habit in two ring-doves, a habit which was next to valueless except as a preparation for further observations. It is natural that during this long period of preparation he should frequently wonder whether the desired end might not be gained more quickly by a different method. It seems probable that a complex situation would have proved more favorable, and that had the two stimuli varied in other respects than in intensity, the animal's attention would more readily have been directed to them and more steadily held upon them. The matter is mentioned here because it is obviously of extreme importance to students of behavior to discover the most efficient means of developing preparatory habits in animals.

In concluding this paper, the writer can not refrain from calling attention to the waste of time which results from the sacrificing of trained animals at the end of an investigation. It should be possible, through exchange, to make the same subject serve in various experiments. And different experimenters, supposing our methods to be reasonably standardized, might study quite different problems on the basis of similar preparatory habits Thus, for example, the doves which in this investigation have been trained to certain visual reactions, might perfectly well be employed for other forms of visual response, or even to greater advantage for studies of the relation of the central nervous system to the acquired responses. It is suggested, therefore, that American investigators who are actively engaged in studies in animal behavior keep in close touch and develop a system of reporting their experiments while in progress, which may serve as a basis for the serviceable exchange of trained subjects The writer happens to have on hand at the moment of writing three tame crows which are highly trained in certain modes of response. The labor of taming and training them would have to be valued at several hundred dollars. It is impossible, under present conditions, to make use of these birds, and unless some other investigator can be found who can take advantage of this preparation, they will have to be either set at liberty or otherwise sacrificed.