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Problem

The problem of color discrimination of animals has been variously discussed by writers. While it is generally conceded that the cones are the receptors of color, the different theories of vision as expounded by Young and Helmholtz, Hering, Ladd-Franklin and others are not always in essential agreement that specific cones are the receptors of specific wave lengths of light.

While form discrimination of rats has been clearly demonstrated in the researches of Fields, Fritz, Lashley and others, the discrimination of color by the lower forms of animals is not so well established.

Writers also differ as to primates, but since the infra-human eye has many of the morphological and anatomical characteristics of the human eye it is reasonable to assume that the functions are similar. As the functional aspects become more nearly like those of the human, the perception of color becomes a greater possibility.

There are many pitfalls in the measurement of color discrimination. Color vision tests for humans never involve a technique whereby the subject names a color. He must be able to differentiate colors in some fashion. Even here the element of differential brightness, reflection factor or albedo is highly important. Also the factor of saturation is important. Many persons who fail the low saturation test objects of the Ishihara Test will match yarns perfectly or may never have trouble with signal lights. According to Benedict, Gorman, Higgins and Lauer (1934) only a small percentage of color blind persons will fail to discriminate color bands of equated intensities. The experiments were made using very rigid controls.

To our knowledge there has been little work on the effect of albedo or reflection factor with respect to color discrimination in the spider monkey. Crawford (1935) carried out an experiment on the effects of brightness on color discrimination by the rhesus monkey using the Yerkes-Watson light-discrimination apparatus. Research by Trendelenberg and Schmidt (1930) has shown that the

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macaques have color vision, within the limit of the test applied, comparable to that of man. Klüver (1933) has shown excellent retention ability to exist in the Java monkey for weight differentiation, and Locke (1935) has shown color constancy in the squirrel money. Grether (1939), Kinnaman (1902), and Bierens de Haan (1925) found that macaques are capable of color discrimination. Watson (1909) found the same to be true in the cebus, new-world monkey. Grether (ibid) tested a spider monkey for difference limen at three points in the spectrum and found discriminatory ability superior to man.

The problem set up for experimental investigation may be stated in the form of a question: Is albedo a definite factor in the apparent color discrimination in the spider monkey (genus Ateleus)?

We have assumed for the purposes of this experiment that, (a) both monkeys are normally responding spider monkeys; (b) raisins as a reward are a sufficiently strong motivating stimulus; (c) odor of food in the experiment is not concentrated in any one spot so as to give any clue as to correct response; (d) all chambers in response box are equally accessible; and (e) the small variations in temperature and/or climatic conditions, etc. will not hinder or accelerate the response of the animals.

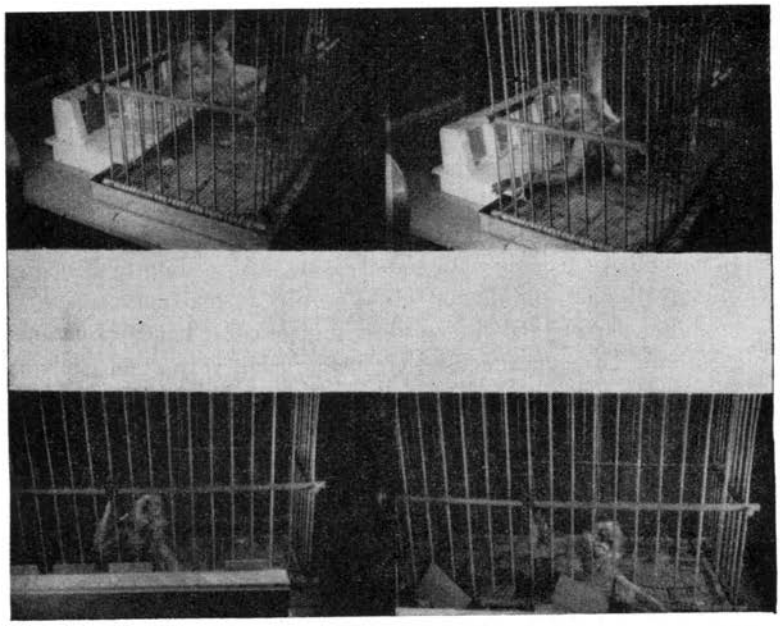


Figure 1. Restraining cage and problem box. Note the five compartments before the animals at the top.

Apparatus

The apparatus consisted of an experimental cage, the problem box having five compartments with five different covers for each series, and sufficient seedless raisins to make the necessary trials. The details will be described in sections.

1. Restraining cage: Cage, 2 ft. x 2½ ft. x 3½ ft. constructed of ¼ in. and ½ in. wooden dowels spaced 1½ in. apart. Finished in light color varnish. Flooring of cage is constructed of ½ in. hardware cloth so droppings will fall into metal tray below.
2. Response box: As shown in accompanying pictures, the box is of wood and painted dull white. It is 26½ in. long, 12 in. wide, and 6 in. high. The chambers are 7½ in. from one edge of the box. (This is easy arm reach for the monkeys.) This edge is placed next to the cage at each presentation. Five multiple-choice chambers in front of which the stimulus panels are placed measure 3½ in. x 6 in. x 4 in. The edge which was presented to the monkeys during the experiment is set an an angle of 20 degrees from the vertical away from the forward edge. This facilitates placing the panels over the openings of the compartments. There is 1½ in. between each chamber so the panels will not be pulled down accidentally by the animals.
3. Panels: These were made of 3½ in. x 5½ in. press board. The panels used in Series 2 to 5 were painted with the following described colors:
   a. In series 2 and 3 Home-Cote enamel was used. This paint was used without mixing with other colors, and are described by the following trade names: silver gray, lemon yellow, apple green, bright blue, and dark red.
   b. In Series 4 Benjamin Sani-flat deep red enamel was taken as standard, and various amounts of artist tint oils, black and white, were added to obtain the different values.
   c. In Series 5 Benjamin Sani-flat deep red enamel was again taken as standard. Benjamin Sani-flat colors, deep yellow, and white, were used with mixtures of artist tint oils, black and blue, to produce the subjectively albedo-equated colors.

After painting, the panels used in Series 2 to 5 were tested for approximate reflection factor by shining a F.R. tungsten photography spotlight through a circular hole in a cardboard shield to allow a spot of light to shine upon each panel as it was tested. The distance from the spotlight to the shield was 10 in., and the distance from the shield to the panel being tested was also 10 in. At an approximate angle of 15 degrees from the horizontal, a Weston light-meter was placed 1 in. from panel being tested. The following light-meter readings were obtained from the painted panels used in Series 2 to 5:

a. From the panels used in Series 2 and 3, these readings were obtained: silver gray (8.0); lemon yellow (10.0); apple green (3.9); bright blue (4.1); and dark red (4.0).

b. From the panels used in Series 4, these readings were obtained: light red (5.5); medium light red (4.9); standard red (3.1); medium dark red (2.2); and dark red (1.8). Three panels originally used in this series, and between which the animals were unable to discriminate, gave these readings: medium light red (3.9); standard red (3.1); and medium dark red (2.6). It should be noted that the standard red originally used was retained in the final test series.

c. From the panels used in Series 5, these readings were obtained: red (3.1) (This was the standard red used also in Series 4); yellow (4.1); gray (4.1); blue (2.9); and green (2.5). It should be noted that there is much less disparity between these readings than with readings for the unequated colors used in Series 2 and 3.

4. Illumination used. One 60-watt tungsten light bulb hung 1½ ft. above the problem box at an approximate angle of 15 degrees to the panels.

General Method and Procedure

The subjects used were two spider monkeys (male and female) of the genus Ateleus. They were both 13 months old and bore the names of Susie and Toby. Both are of the common Central American variety of spider monkey which has light-colored hair and skin and dark head, hands, feet, elbows, and knees. They were both under the care of the experimenter soon after their capture, being taken from the jungles of Nicaragua at the approximate age of 4 months and have been kept separate from other animals since that

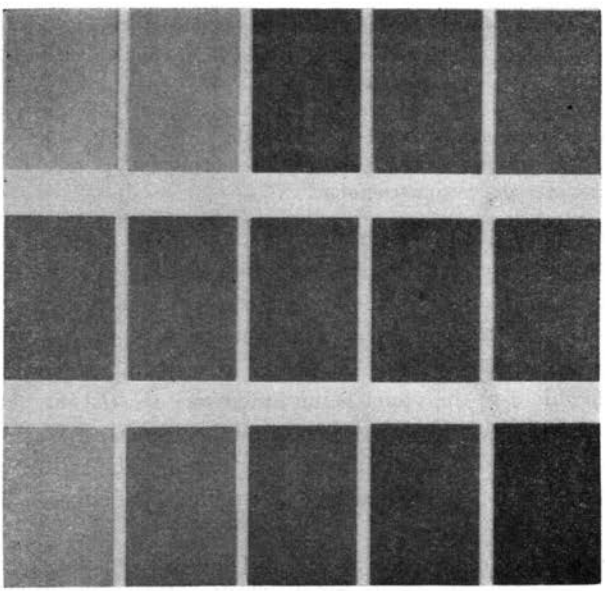


Figure II. Range of albedo used as shown by panchromatic film.

time. At the age of five months, they were brought to the United States and have, since that time, been in good health and have apparently become used to their new environment without ill effect. At the time of the test Toby (m) weighed 5 lb., and Susie (f) weighed 6½ lb.

After habituating the two animals to being separated from each other, a special cage was used to confine the movements of the animal during the experimental procedure. The experimental cage was set on a table and lights placed so as to illuminate the test objects at from 10-15 foot candles of light. The experiments were mostly run late in the afternoon and a mixture of artificial and mazda light illiminated the color panels.

Raisins were placed in the compartments of the multiple-choice problem box, and the panels were placed over the compartments. The box, which was easily moved, was then presented to the animal being tested. The construction of the box permitted its being placed against the restraining cage in a manner which placed the panels the same distance from the cage in each trial. The monkeys quickly learned that by pulling down the panels on the problem box they would find raisins in the compartments.

Series 1—Method and Procedure

The first test with the use of the multiple-choice response box was made to determine the animals predisposition for spatial position of the response chambers of the problem box. (This series and the one following were also used as a method of adaptation to the apparatus.) All five compartments of the box were covered with blank panels after the monkeys had been initially introduced to the reward-in-the-box concept. Raisins were placed in all compartments to determine true predisposition. After each choice was made by the animal being tested, the problem box was withdrawn, the raisins and panels were replaced, and the box was again presented to the animal.

Early in this series it was found that the animal had a tendency to reach for the panel covering the compartment at which he had last been rewarded. For this reason, such a rapid representation of the problem had to be discontinued. This was accomplished by removing the response box after each single choice and delaying its replacement for a longer interval. The effect of this delay was that the animal being tested approached each choice situation with a more or less fresh attitude or postural approach.

Results

Fifty trials under this delayed situation showed no significant predisposition by either animal for relative spatial position of the compartments of the problem box.

Table I

Data on Predisposition for Spatial Position

Position on Response Box	TOBY 1	2	3	4	5	SUSIE 1	2	3	4	5
	6	1	3	8	2	6	2	1	9	5
	9	4	5	14	7	15	4	3	10	8
Numbered by	12	11	16	15	10	16	14	7	12	11
order of	18	13	17	25	21	24	17	13	21	22
response	19	20	22	26	30	25	20	18	23	32
	23	27	24	29	37	26	29	19	28	40
	31	28	34	33		30	34	27	31	48
	32	35	47	36	41	37	36	42	33	49
	39	43			42	39	38	44	35	
	40	44	38		46	47	50	46	41	
	49	45	48						43	
	50								45	
Total Responses	12	11	10	8	9	10	10	10	12	8

Application of chi-square technique shows all variations between compartments to be within the limits of chance.

Series 2—Method and Procedure

In the second series the blank panels were replaced by the prepared colored panels (reflection factor unequated) to determine predisposition for color. The positioning of the panels was constant because of the lack of spatial predisposition by the monkeys.

Results

No significant predisposition for color was found.

Table II

Data on Predisposition for Color

Color:	TOBY Rd	Yw	Gn	Gy	Bu	SUSIE Rd	Yw	Gn	Gy	Bu
	1	2	13	6	3	5	1	3	4	2
	4	5	18	14	15	7	6	14	12	13
	7	8	31	20	23	8	11	20	15	23
Numbered	9	11	27	22	33	9	16	21	19	25
by order	10	16	28	29	36	10	17	29	24	27
of response	12	19	34	35	45	18	30	36	26	28
	17	26	40	38	46	22	31	43	39	41
	24	30	48	41	49	32	33	45	40	42
	25	31		44		35	34	49	46	44
	32	37		47		37	38			50
	39	42				47	48			
	43	50								
Total Responses:	12	12	8	10	8	11	11	9	9	10

A chi-square test shows the results to be well within the range of chance variations.

Series 3—Method and Procedure

In this series using the unequated colors, the raisin was placed behind the red panel only. The panels were placed at random and the problem box was only removed after the correct choice was made. The animals frequently knocked down several panels before finding the raisin. Forty trials were given each monkey each day for ten days.

Results

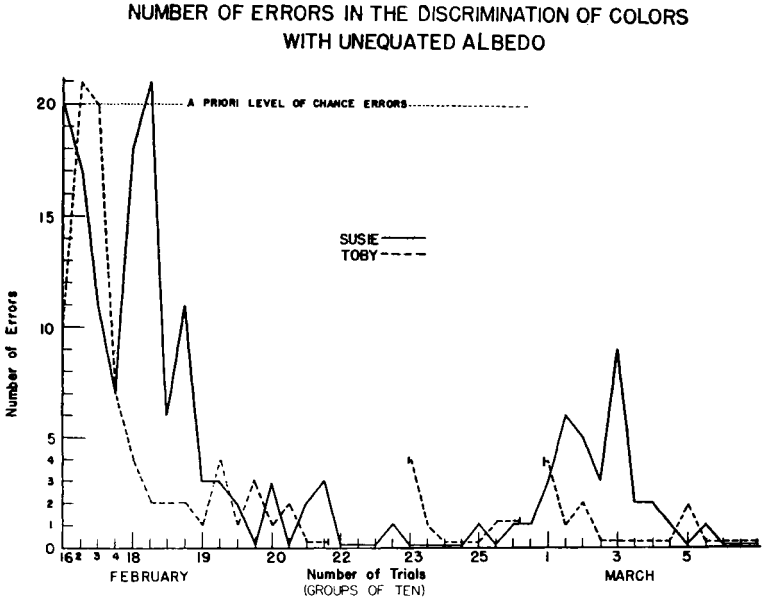
By the third day, both animals averaged only 2 errors in each set of 10 complete trials. These sets of 10 trials were used as units of measurement. This average Susie continued for 18 sets of 10 trials. Toby became uncooperative after 8 sets.

Susie was, as a rule, more playful and less easily disturbed than Toby. He was more alert, but any unusual movement or noise caused him to lose interest in the experimental problem.

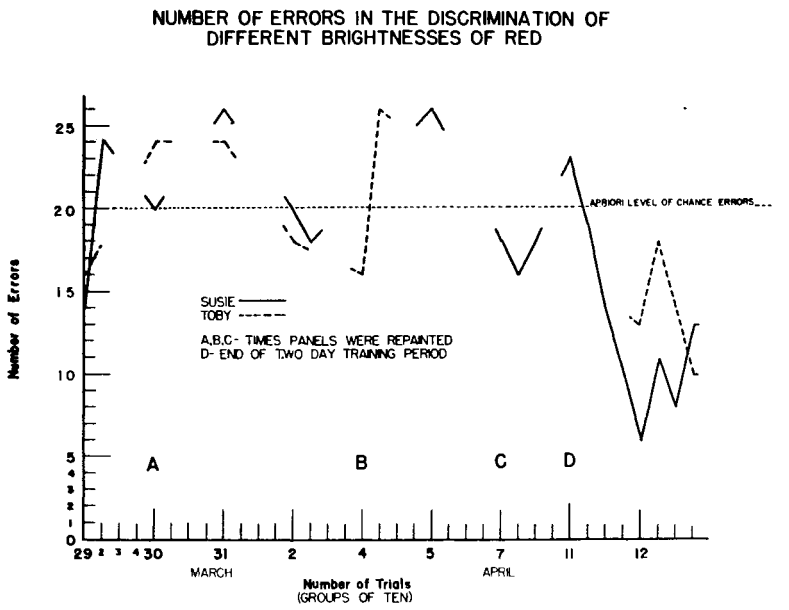
Over the last 4 sets of 10 trials each monkey made only one error. The significant evidence of conditioning is obvious. These data are given in Graph I.

Series 4—Method and Procedure

The same method was used as in the preceding part, but the unequated colored panels were replaced by panels painted different



Graph I.



Graph II.

values of red. An attempt was made to condition the animals to one standard value. The purpose, coupled with the following step, was to find the role of albedo as a factor in color in discrimination. Four sets of 10 trials per animal were run each day for 9 days.

Results

It was found necessary to repaint the panels to a greater value difference on three separate occasions during the series in order to be able to secure a differential threshold. At first, no recordable data were obtained because the animals were unable to discriminate the reds. Susie was playful at first, but when she was unable to make an adjustment to the problem, she showed definite signs of frustration. She sat in the center of the cage and screamed. Later she either showed disinterest or would play at the problem going continually from left to right on the response box without trying to discriminate. This left-to-right pattern perseverated to some extent in all later trials.

Toby was easily discouraged and made only five attempts at the new problem when this series was first presented him. Later, when a greater value difference was given him, he worked somewhat better. His normal reaction to such frustration was to cling to a corner of the cage and chirp.

After six days of presenting the red panels to the animals, during which time they became more and more frustrated, it was found necessary to shift to the subjectively-equated colors. Following this, an attempt was again made to train the animals to discriminate between the different values of red. This was done by beginning each day's training period with the subjectively-equated panels of different colors, and, when the animal was working well under these conditions, the red panels were substituted, one at a time, for the other colored panels. The period between the 7th and 11th of April 1951 was used for the above described training. The monkeys worked somewhat better after training, but only slight ability has as yet been shown to discriminate albedo. It should be noted that this ability is much inferior to the ability shown by the animals in their discrimination of color. The results of this work is shown in Graph II.

Series 5—Method and Procedure

The same methods were used as in Series 3, but the panels used were painted with colors that had been subjectively albedo-equated. Four sets of 10 trials were given each monkey.

Results

Over the 4 sets of 10 trials, Toby made no errors, and Susie made but two. This was considered a sufficient criterion of mastery.

Summary of Experimental Results

No spatial or color predisposition was found for either animal. Definite discriminatory ability was exhibited by both animals for the unequated colors. Discriminatory ability with the subjectively albedo-equated colors was found to be on the same level as the previously learned unequated colors. No difficulty was found in the immediate transference from the unequated to the subjectively-equated colors. On the other hand, great difficulty was encountered with the values of red, and only slight ability by the monkeys to discriminate albedo has been exhibited up to the present.

Conclusion

Within the limits of the experimental design, number of subjects, and conditions of this study, albedo (reflection factor) shows little effect upon the discrimination of color by the spider monkey. The immediate transference from the unequated colors to the subjectively albedo-equated colors, coupled with the slight ability exhibited by the animals to make discrimination among the different values of red, up to the present time, seems to warrant this conclusion. Further studies are being made.

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