AN INVESTIGATION OF COLOR

VISION IN THE WHITE RAT

A THESIS

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Introduction

The purpose of this experiment was to determine whether or not the albino rat can distinguish between red and green as pure chroma when intensity differences have been equated. Assuming the animal's ability to detect differences in intensity, it was further hoped that if the subjects proved unable to make the discrimination between chroma the experiment would indicate the minimum difference in intensity essential to perfect discrimination.

The problem is by no means original, but no small amount of controversy still exists as to its proper solution. As early as 1907 Yerkes[1] performed a series of experiments upon the dancing mouse in an attempt to prove or disprove that animal's ability to distinguish pure chroma. Though not entirely conclusive, his results indicate that one mouse may have been able to recognize colors as such. The red end of the spectrum Yerkes found to be extremely weak in all of his subjects.

Three years later Waugh[2] found that white mice could discriminate between Bradley orange, red and blue papers; but when filters were substituted the discrimination broke down.

Watson and Watson[3] in 1913 trained rats to differentiate between red and green lights, without attempting to equate intensities. Red was the positive stimulus. It was discovered that the response was

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1 R. M. Yerkes The Dancing Mouse, MacMillan, New York, 1907, pp. 21 and 290.

2 K. T. Waugh "Role of Vision in Mental Life of Mouse" JOURNAL OF COMPARATIVE NEUROLOGY AND PSYCHOLOGY, 1910, 20, 549-599.

3 J. B. Watson and M. I. Watson "A Study of the Responses of Vertebrates to Monochromatic Light" JOURNAL OF ANIMAL BEHAVIOR, 1913, 3, 1-14

not at all affected when the red light was extinguished. The animals were not responding to color, in fact the red light appeared to lie below their perceptive threshold, but their response was based upon an avoidance of the lighted chamber. The experimenters concluded that long wave-lengths do not stimulate the visual receptors of rodents, and that color vision is probably non-existent in the species.

In 1927 Hopkins[4] used the Yerkes apparatus with minor modifications to train mice to respond to colored papers. Blue was confused with Hering gray number 13, and red with Hering gray number 49.

Munn[5], experimenting with hooded rats in 1932, trained his subjects to discriminate between colored papers, using red and gray, green and gray, blue and gray, and yellow and gray. He then substituted various grays until he had found four grays which the animals could not distinguish from his four primary colors. Finding that green was confused with Hering gray number 8, and that yellow was confused with Hering gray number 8 or 7, and having thus equated the brightness of the two chromas, Munn attempted to set up a discrimination between yellow and green. After 850 trials the rodents evidenced no ability to discriminate, and Munn concludes that they possessed no color vision, being able to distinguish on the basis of intensity only.

In 1933, Coleman and Hamilton[6] using Chinese hooded rats as subjects, and employing Lashley's apparatus wherein the rat is compelled to jump

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4 A. E. Hopkins "Vision and Retinal Structure in Mice", PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCE, 1927, 13, 488-491

5 N. L. Munn "An Investigation of Color Vision in the Hooded Rat", JOURNAL OF GENETIC PSYCHOLOGY, 1932, 40-41, 351-361

6 T. B. Coleman & W. F. Hamilton "Colorblindness in the Rat", JOURNAL OF COMPARATIVE PSYCHOLOGY, 1933, 15, 177-181

through the stimulating door, trained their subjects to respond to colored papers. The brightness of the stimulating color was approximated step-by-step with Hering grays. When the intensity of the stimulating color and the gray variable was not definitely differentiated the response broke down. Untrained rats, not having learned the brightness discrimination, could not be taught to distinguish between two colors of approximately equal intensity. No discrimination could be built up between reds, blues, greens, and grays when the intensities had been equated.

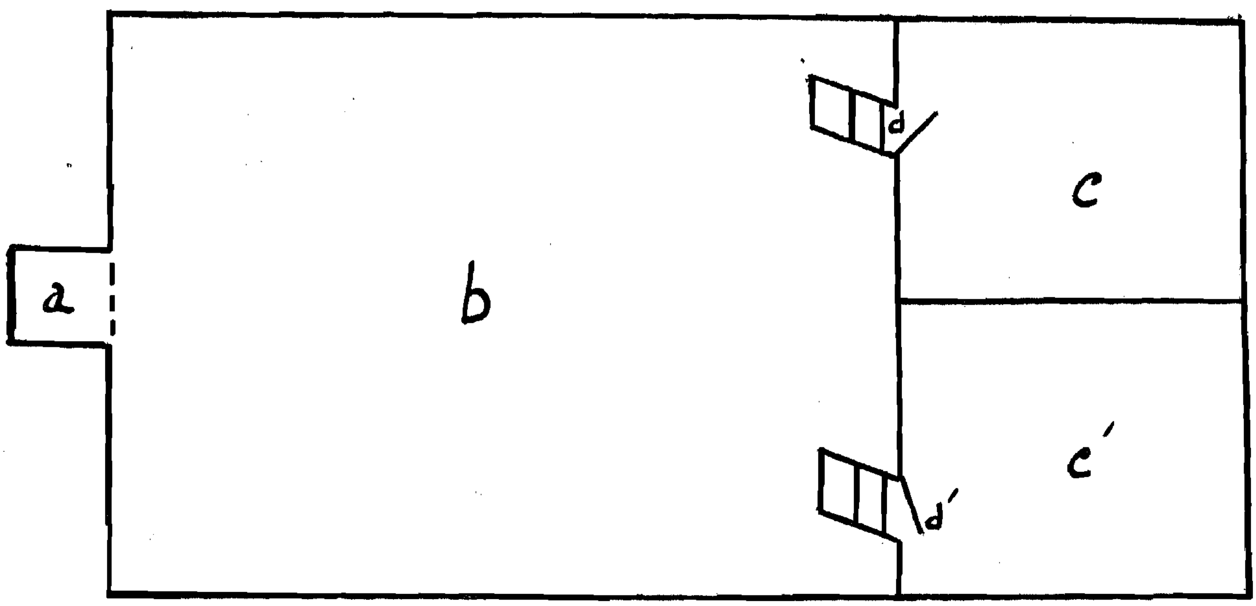
Though many more experiments along this line of research have been performed, the work cited above is typical in method, results and conclusions. In general the findings of all experimenters who have sought the answer to the questions under consideration can be summarized in three points. (1) Slight and unsupported evidence for color vision in one animal was discovered by one experimenter. (2) The great weight of evidence is against the existence of color vision in rodents. (3) Practically all evidence points toward discriminatory ability which depends upon perception of the intensity variable.

Apparatus

The apparatus used in this experiment consists of the usual problem box including a starting box, a discrimination chamber and the two feeding boxes. Figure I presents a top view of the apparatus. The starting box (a) is covered with a sliding top and opens into the discrimination chamber (b), the inside of which is painted black, through a sliding door which is lifted by the experimenter. The starting box contains approximately one half inch of water to facilitate the punishment and make the rat enter the discrimination chamber as soon as the sliding door is raised. From the discrimination chamber the rat gains access to the feeding boxes (c and c') by pushing open the doors (d and d'). In front of each door is placed a small trap resting upon a weak spring. The weight of the animal depresses the trap and closes an electric circuit, thus flashing a light in front of the experimenter and indicating the door the rat has chosen.

Figure I

Top View of the Problem Box

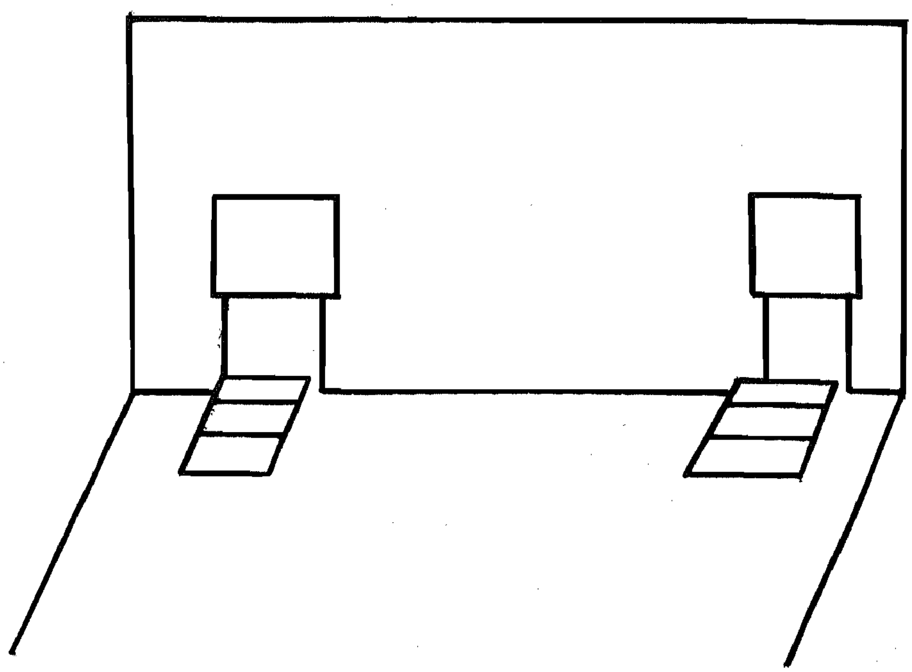


When the correct door is selected the rat enters the feeding box and is allowed to take a mouthful of food from the tray. The traps are covered by an electric grid charged with 24 volts alternating current which is used as punishment when the incorrect door is chosen.

Figure II illustrates the doors and stimulating lights which confront the subject in the discrimination chamber. The colored light emerges from the square windows placed directly above the doors leading to the feeding boxes. The doors and the traps bearing the punishment grills are shown in the illustration. The entire problem box is covered with a lid hinged in the center.

Figure II

Doors to Feeding Boxes and Stimulating Lights

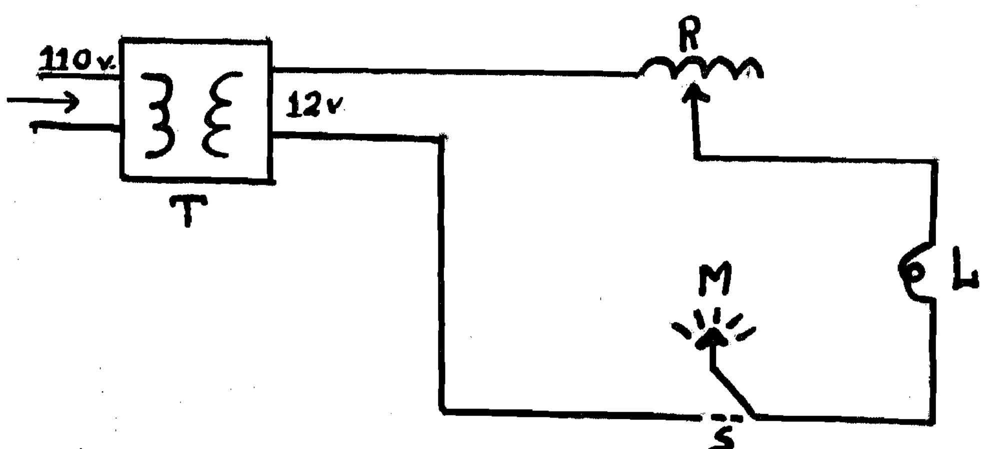


The stimuli consist of colored lights projected by a 12 volt bulb through gelatin slides fitted in grooves over the doors to the feeding boxes. Each bulb is wired independently from a transformer. Either light may be thrown into a circuit with a delicate Weston ammeter measuring the amount of resistance in the circuit. This device makes possible the accurate measurement of the relative intensity of the two lights. In each of the independent circuits is a series of resistors which are used to vary the amount of current flowing through the bulbs. By using the resistors and the ammeter, sensitive to a change of 1/1000 of an ampere, the brightness of either light can at any time be measured accurately and varied at will.

Figure III shows the wiring diagram for one light. Both bulbs are wired exactly alike, using the same size and length of wire, and identical resistors.

Figure III

Wiring Diagram for Stimulating Light



The transformer (T) puts out a 12 volt current which is varied by the use of the resistor (R). The current then flows through the light (L). The switch (S) can be thrown to cut the current through the ammeter (M) and measure the exact amount of resistance in the circuit.

The apparatus described above was used in the main experiment. A preliminary experiment was conducted, using apparatus that was identical save for the absence of punishment grills and doors in the apertures leading to the feeding boxes.

To equate any chance variation in the two bulbs used in the experiment, the lights were exchanged frequently, and the ammeter reading for each circuit was recorded at the completion of every five trials.

The colored filters were constructed of regular spot-light gelatin encased in a light metal frame. The slides were approximately two inches square. Because ordinary gelatin does not produce pure monochromatic light it was planned to substitute Wrattan filters if any question arose as to the rat's ability to distinguish pure chroma.

Method[1]

The subjects of the main experiment were two male albino rats, 60 days old when the experiment was begun. Taken from an inbred colony and put on a diet of bran mash, wheat grain and milk, supplemented twice each week with green vegetables and cooked meat, they were in excellent health throughout the entire experimental period. The subjects for the preliminary experiment were three male and three female adult albino rats. They were taken from the same colony.

To orient the animals to the problem box the experimenter allowed them to run through the discrimination chamber, open the doors to the feeding boxes, and eat their meals therein for the six days immediately preceding the beginning of the training period. During this period of orientation no stimulus or punishment was employed, and food was available in both feeding boxes.

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[1] The method described below is that which was employed in the main experiment. The preliminary experiment was conducted with the sole purpose of building up a scientific technique for the management of the main experiment. The results of the preliminary work were carefully recorded, but, because the technique with which they were collected had not yet been perfected, will be referred to only once in this report.

During the training period and the subsequent testing period the animals were given 20 trials perdiem. All experimenting was done at night to avoid distraction through extraneous visual stimulation. Furthermore the rat is by nature a nocturnal animal and is most active at night. The lights above the doors opening into the feeding boxes were adjusted at 450 milliamperes for the red and 375 milliamperes for the green. Red, being the positive stimulus, was made markedly more intense than the green. The door below the green light was locked, and the metal grid directly before this door was charged with 24 volts alternating current. During the diurnal 20 trials the red light and food were switched from one side to the other in chance order.

The rat was placed in the starting box and allowed to remain there until his feet were quite wet. The sliding door was then raised and as the animal stepped into the discrimination chamber the door was lowered behind him. As soon as either door was approached and an attempt was made to open it the signal lights in front of the experimenter indicated the rat's choice, and it was immediately recorded. If the wrong door was selected the animal received an electric shock and then nearly always ran at once to the other door. When the subject had tasted the bran mash which was in the feeding tray he was returned to the starting box for another trial. The return trip was always made by the same route regardless of which feeding box had been entered. At the conclusion of the twentieth trial the animal was fed sparingly of the regular diet and returned to the living cage. Approximately 24 hours thus elapsed between feeding time and the period of testing.

The standard of learning was arbitrarily set at 90 per cent correct for two consecutive days. This meant a minimum of 36 correct responses out of 40 trials. Diurnal variations in accuracy were the cause of the two-day provision.

An attempt to eliminate the possibility of guidance by non-visual clues included four major precautions. (1) Practically all experimenting was done at night, and the animal worked in a closed box. The experimenter was not visible to the subject at any time during the selection of the stimulus and the subsequent response. (2) The partition between the feeding boxes was constructed of coarse wire screen, and the feeding tray extended into both feeding boxes, being covered with a perforated metal lid in the "wrong" feeding chamber. This arrangement was intended to remove all possibility of olfactory guidance. (3) The positive stimulus was alternated in chance order from one door to the other. (4) The return trip from the food box was always made by the same route.

When the rats had achieved the standard of learning previously stated, the testing period was immediately begun. The door below the green light was unlocked, and no electric shock was given. The intensity of the red light was gradually decreased, and that of the green was simultaneously increased. Throughout the testing period the following procedure was strictly adhered to. Ten trials were given at the training intensity, that is with the red at 450 and the green at 375 milliamperes.

Then ten trials were given at the testing intensity[2], whatever the latter happened to be at that day. In this way a constant check was kept upon the animal's ability to maintain its discriminatory ability under training conditions, and at the same time the effect of decreasing the difference in intensity between the two lights was clearly indicated.

Results and Discussion

The rats learned to respond to the red light after approximately 300 trials. As has been stated the red light was much brighter than the green. With Watson and Watson's results in mind it was considered expedient to determine whether or not the animals were responding to the red light, or even to the lights at all. Accordingly both lights were entirely eliminated. The rats were given 20 trials under these conditions and only three responses were forthcoming. This seemed to prove at least that the response was based directly upon the lights. Next the red light was thrown on, but the green was left dark. The 20 trials under these conditions showed an average efficiency of 92 per cent for one rat and 96 per cent for the other. These two sets of results were taken to mean that the animal's responses were based upon the red light as the positive stimulus.

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2 Throughout the report the term "testing intensity" will be used to mean that particular difference in brightness at which the rat is being tested upon a particular day. "Training intensity" refers to the relative intensities at which the rats were trained to respond. (See page 8 of the report)

With this fact established the experimenter proceeded to decrease the intensity of the red light and increase that of the green. In considering the following results it is well to note that an accuracy of more than 50 per cent does not necessarily denote learning. Lashley[1] states that in the typical problem box and under the common practice of chance variation of stimuli, the rat can attain an average of 70 per cent correct responses without responding to any controlled stimulus.

Table I presents the material illustrated in Figures IV, V, and VI.

Table I

Individual Records of Both Subjects and Their Combined Average

Number Milliamps by which Red Exceeds Green	Per cent of Responses Correct		
	R.E.C.	N.E.C.	Average of Both
+75	90	100	95
+25	70	60	65
-25	40	20	30
-50	40	30	35
-75	30	50	40
-100	20	30	25
-150	15	19	17

In the figures named the individual record of each subject is graphically represented, as is the combined average of the two. Figure VI shows that

[1] K. S.Lashley "The Mechanics of Vision: I A Method for Rapid Analysis of Pattern Vision in the Rat", JOURNAL OF GENETIC PSYCHOLOGY, 1929, 37, 453-460.

when the difference between the two intensities was decreased 50 milliamperes a drop of 30 per cent in the accuracy of the response followed. A second decrease in the intensity difference (amounting to 50 milliamperes) was accompanied by a drop of an additional 35 per cent in the accuracy of response. Subsequent decreases of 25, 25, and 50 milliamperes (which brought the intensity of the green light well above that of the red) were accompanied by a slight rise and then a larger fall in the level of performance. Since the increase in accuracy of response actually brought the record up to only 40 per cent correct it is hardly to be considered significant.

Figures IV, V, and VI bear a superimposed curve of broken line which indicates in each case the accuracy of performance exhibited by the subject in question when the lights were at training intensity. As has been previously stated, during the testing period each subject was given ten trials at training intensity and then ten more at the testing intensity for that day. The broken line in each graph is based upon the percentage of accurate responses occurring during the ten trials given directly before the intensity of the lights was varied.

It appears safe to conclude that a minimum difference of 75 milliamperes in the intensities of the two lights was essential to perfect or near-perfect discrimination. It may be argued that the rats were trained to discriminate between two colored lights set at 450 and 375 milliamperes respectively, and that they might have learned to make a finer discriminatory response if they had been given a greater number of trials with the lights adjusted, for example, a 450 and 375

Figure IV

Individual Record of N.E.C.

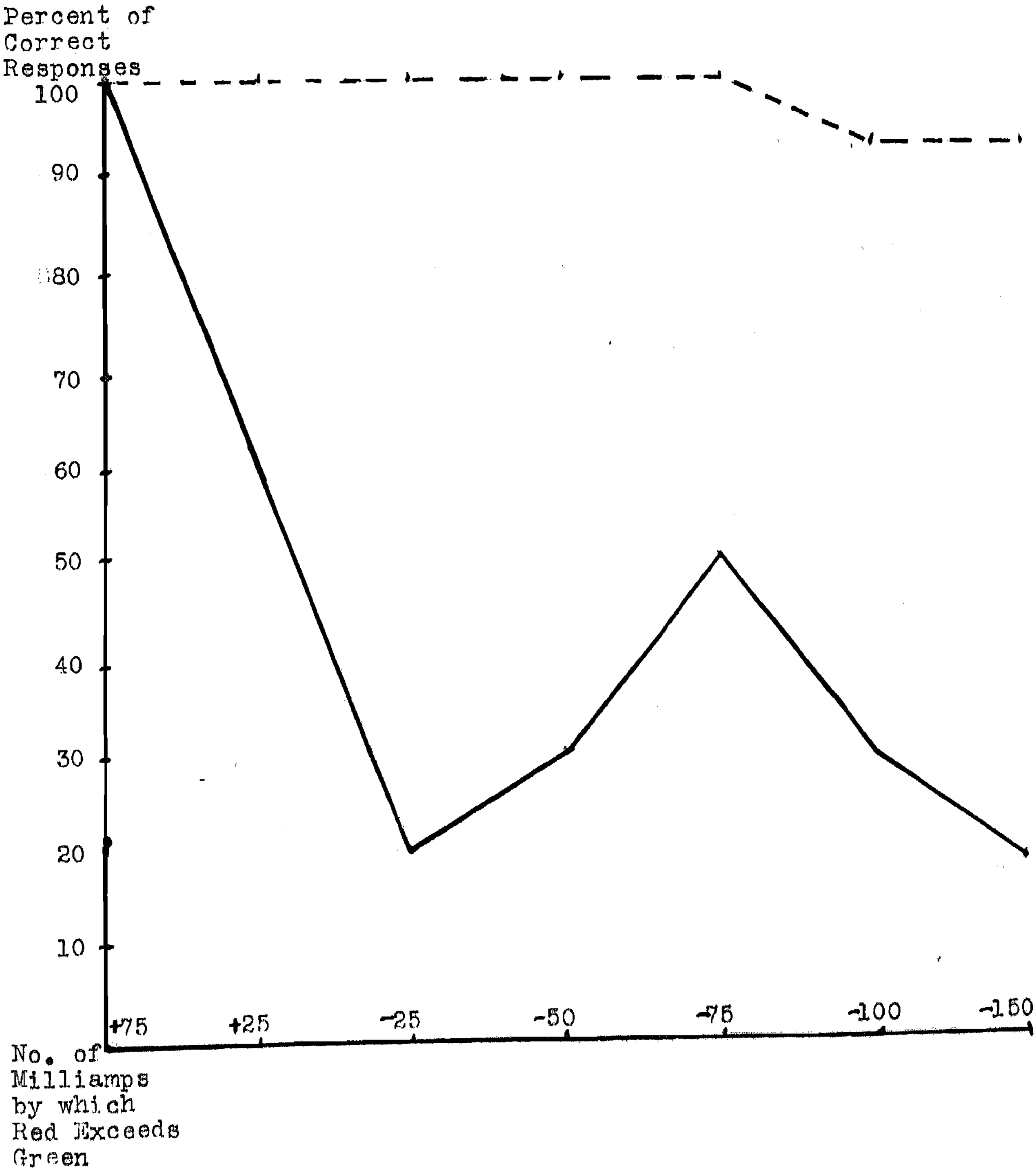


Figure V

Individual Record of R.E.C.

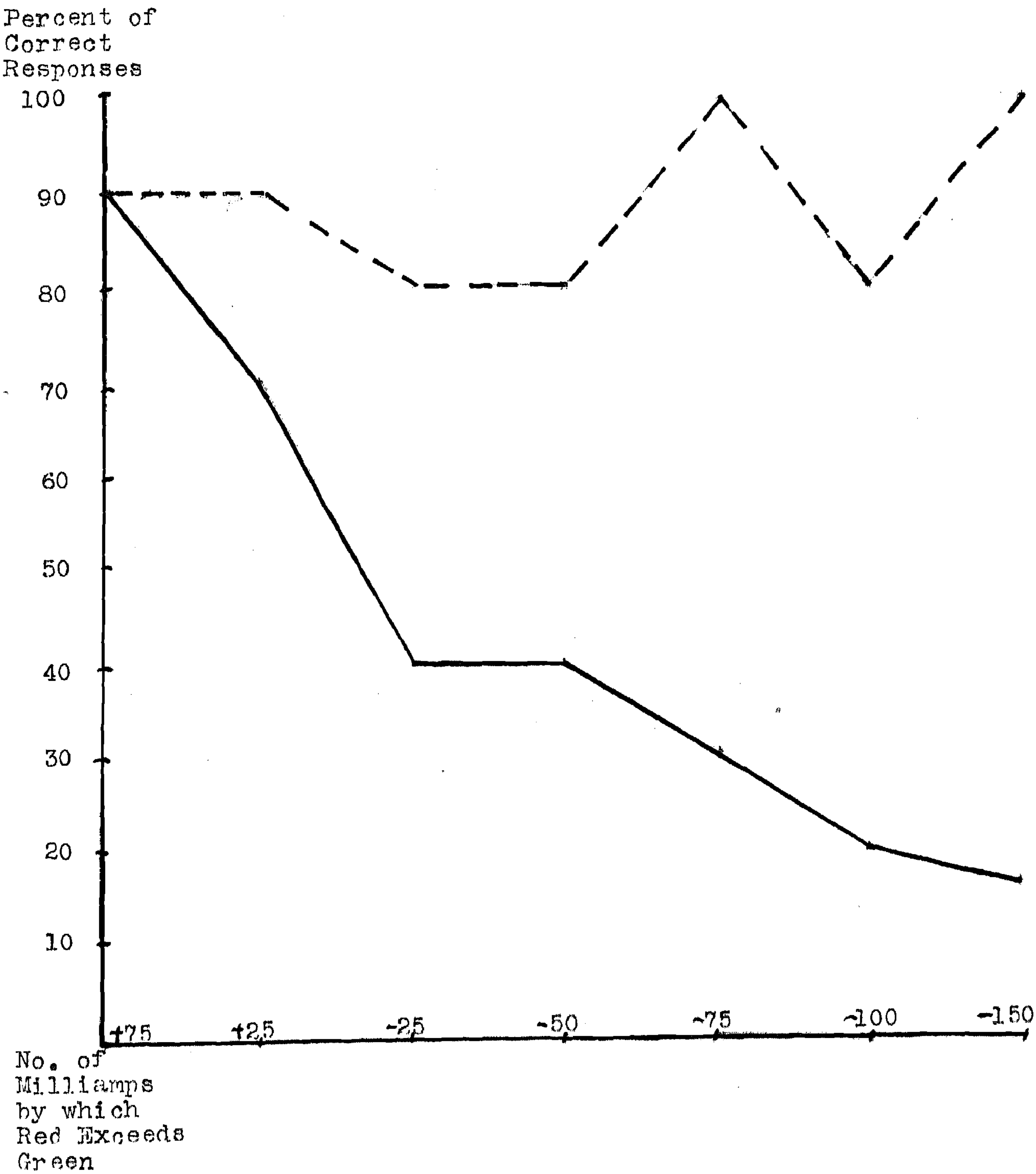
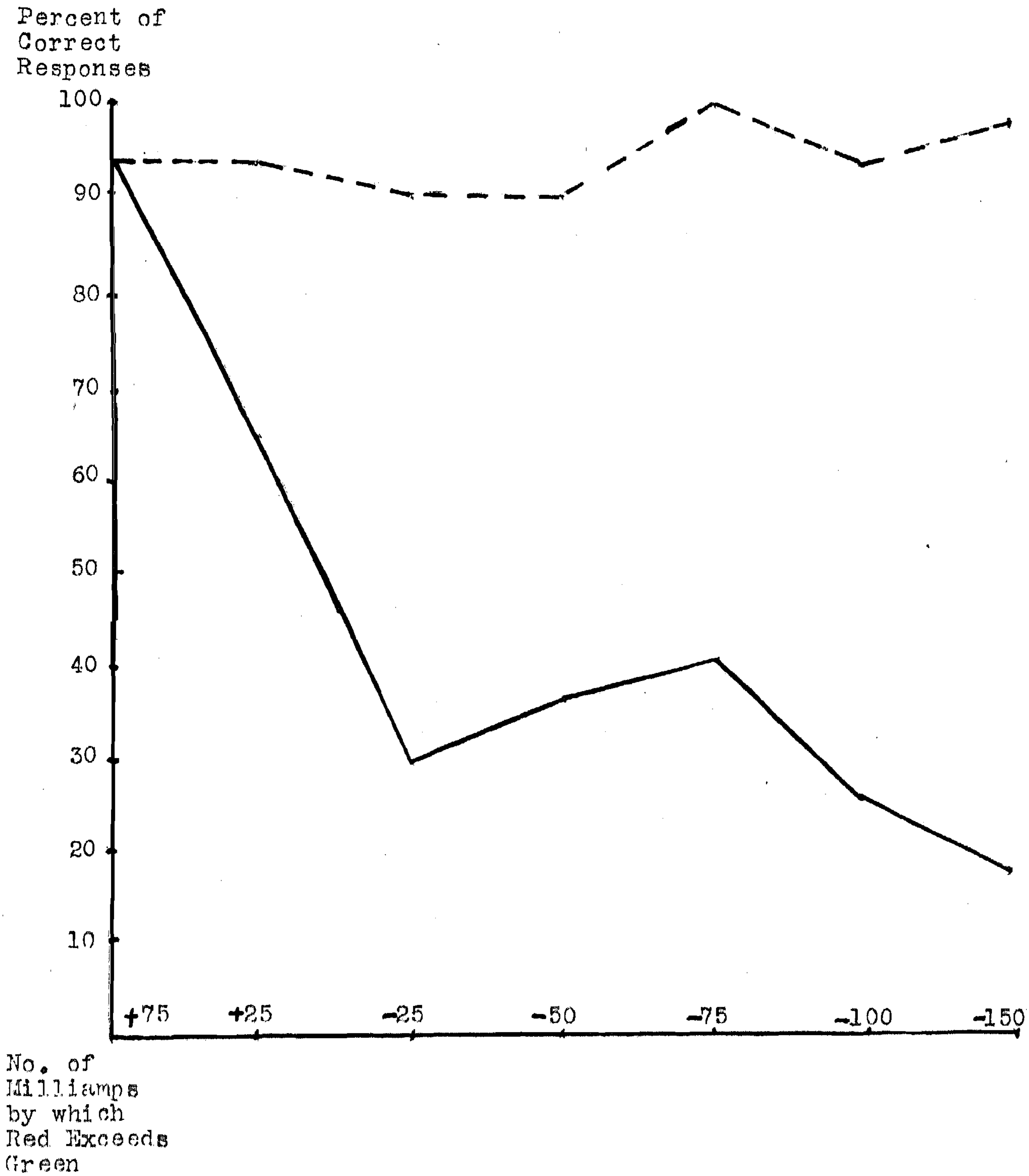


Figure VI

Record of Combined Averages

for Both Subjects



milliamperes. It is true that the subjects were given only ten trials at each testing intensity, and it is not illogical to assume that they might conceivably have learned to make a finer distinction given a greater number of trials at the testing intensity. There is, however, one bit of evidence taken from the results of the preliminary experiment (see page 7, footnote 1 of this report) which tends to disprove any such assumptions. The six subjects of that experiment were given approximately 200 trials at each of the various testing intensities. Although none of these animals achieved a perfect record at any intensity, it is highly significant that their efficiency (which ranged between 80 and 85 per cent normally) dropped below 60 per cent when the intensities of the two lights were set at a smaller difference than that existent when the red light was adjusted at 475 and the green at 350 milliamperes. Since the subjects of this preliminary experiment achieved a record of approximately 83 per cent correct responses at the training intensity for the main experiment, and then failed to exceed 60 per cent with the lights set at 450 milliamperes for the red and 375 for the green, it seems reasonable to assume that the subjects of the main experiment would have been unable to significantly improve the record which they established at training intensity when the lights were changed to the intensity directly below that at which they were trained, even if they had been allowed several hundred trials.

It should be explained that the green and red gelatins possessed different powers of absorption for the light used. Consequently the readings on the milliameter do not indicate directly the relative intensities of the two lights. The green gelatin absorbs more light than does the red, and for this reason when the readings on the milliameter are equal the red is noticeably brighter than the green. When the red is set at 350 milliamperes and the green at 475, the intensity to the human eye of the two stimuli is approximately equal. At this point the difference in intensities as recorded in Figures IV, V, and VI would be -125.

The above-quoted results appear fairly conclusive, but they could be improved upon in several ways. Four major avenues of improvement are open. The number of subjects should be larger. Finer gradations in intensity should be employed. More trials per subject should be given at each level of intensity. The training period could undoubtedly be markedly shortened if Lashley's apparatus were used.[2] The present writer does not believe that the instituting of these various changes would produce results dissimilar to those listed for this experiment, but it is obvious that the resultant data would be more continuous and the curves built thereon more even and symmetrical.

Conclusions

(1) With the apparatus and method employed in this experiment the subjects thereof were unable to distinguish between red and green as pure chroma. (2) All discriminatory ability evidenced involved perception of intensity differences only. (3) With the apparatus used in this experiment, perfect or near-perfect discrimination was not possible with a difference in intensity of less than plus 75 milliamperes for the red.

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[2] K. S. Lashley, Ibid.

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