Color discrimination by rhesus monkeys¹

DOUGLAS L. MEDIN AND ROGER T. DAVIS

UNIVERSITY OF SOUTH DAKOTA

Rhesus monkeys (*Macaca mulatta*) were trained to discriminate standard stimuli which were Munsell papers differing considerably in Hue, Value, and Chroma. They were then given stimuli lying between the standards and were required to match each stimulus to one of the standards. Matching depended on changes in one dimension, as well as simultaneous changes in two or more dimensions, e.g. a change in Hue and Value was more likely to lead to a shift in matching than a change in either alone. Other Es using unlike stimulus dimensions, e.g. form, size, and color, reported that cues must be equally potent to summate. In the present study, however, additivity occurred in spite of cue dominance.

This study examined the summative effects of hue, lightness, and saturation on discriminations of rhesus monkeys. Since the stimuli were Munsell papers, these dimensions will be referred to as Hue, Value, and Chroma (Judd, 1952). Additivity was defined as more shifts in matching when two or more relevant cues were provided than when only one cue was provided. Warren (1954) showed that monkeys used cues additively in simultaneous discriminations if the cues were of nearly equal potency, but failed to do so if cues were of unequal strength. Lashley (1938), who first reported the latter effect, proposed a mechanism of perceptual dominance in which associative strength became attached to a single dominant stimulus.

Color was a better cue than form or size in several experiments with monkeys (e.g., Draper, 1965). Miles (1965) attributed this to the fact that each of the color dimensions may add to the discriminability of the differences between two objects. Color has three independently variable attributes, unlike spatial cues which are inextricably confounded, e.g., height and size.

Method

The Ss were 13 highly trained rhesus monkeys (*Macaca mulatta*). Nine had received comparable training for 13 years; the other four were progeny of the older Ss and their training paralleled that of their progenitors during the seven years prior to the present study. One of the older Ss failed to complete preliminary training leaving 12 Ss during critical training.

Stimuli were glossy finish Munsell colored papers glued to 2-in. squares of Masonite. A conceptualization of the design is shown in Table 1 along with the specific Munsell colors. Twenty-nine colors were chosen from the green green-yellow part of the spectrum in the following manner. The colored square lowest in Hue, Value and Chroma² ($H_1V_1C_1$) was designated as the Lower Standard. The other stimuli differed from the Lower Standard, in Hue, Value, Chroma, or one of the four possible combinations of these. Each of the seven modes of difference were represented at four equally spaced increasing steps. The color most different from the Lower Standard, i.e., $H_5V_5C_5$, was the Upper Standard.

A WGTA with two minor modifications was used for stimulus presentation: (a) to minimize contrast effects, the test tray was painted to match a Munsell Value 6.0, and a 10-in. square of Munsell matte

finish paper of Value 6.0 was glued around each foodwell; (b) to diminish surface reflectance, the test tray was slanted 50°.

Illumination was provided by an incandescent ceiling light and two fluorescent lights, one over the test tray, the other over the restraining cage. The surface of the test tray reflected 5.9 ft.-c. of light, as measured by a Macbeth Illuminometer. Reflectance readings from the walls about the apparatus averaged 4.2 ft.-c.

In preliminary training the Upper and Lower Standards were presented to Ss in a successive problem paradigm. Two identical stimuli covered the foodwells on each trial. The Lower Standard pair signaled S that the left (or righthand) foodwell contained a raisin reward. The Upper Standard pair designated a response to the right (or lefthand) position as correct. Monkeys were given 40 trials a day in which the alternative sets of standard stimuli occurred in a random but balanced order. Training continued until S reached a criterion of 90 percent correct responses on any day, or until S failed to meet the criterion in 20 days. Twelve of the 13 Ss learned the appropriate position response to each pair of standards and proceeded to critical training.

Twenty-seven 3-trial problems were given to each S daily for 30 days during critical training. The Upper and Lower pairs of standard stimuli were presented in a random order on the first two trials of each problem. On the third trial, one of the 27 pairs of variable stimuli were presented at random. Differential reinforcement was given on the first two trials of a problem, but both foodwells were reinforced on the third trial. Ss' responses on the critical Trial 3 indicated to E which cue or combination of cues the monkeys used. For example, suppose a stimulus had a Hue identical to the Lower Standard but the Value and Chroma of the Upper Standard. A response to the position appropriate to the Lower Standard indicated that S discriminated on the basis of Hue. To reduce extraneous error, third trial responses were not included in the analysis if S had erred on either of the two preceding trials. These procedures differed from most studies of cue additivity in that judgments rather than errors were the dependent variable. However, Es equated errors and judgments at the Upper Standard which was the combination of Hue, Value, and Chroma at Step 5.

Table 1. Munsell Specification of Colors Employed²

Lower Standard = H ₁ V ₁ C ₁ 2.5G 5/6		Upper Standard = H ₅ V ₅ C ₅ 8.45GY 7/10		
Variable				
Stimuli	Step 1	Step 2	Step 3	Step 4
Hue	H ₂ V ₁ C ₁ 1.25G 5/6	H ₃ V ₁ C ₁ 10GY 5/6	H ₄ V ₁ C ₁ 8.75GY 5/6	H ₅ V ₁ C ₁ 7.5GY 5/6
Value	H ₁ V ₂ C ₁ 2.5G 5.5/6	H ₁ V ₃ C ₁ 2.5G 6/6	H ₁ V ₄ C ₁ 2.5G 6.5/6	H ₁ V ₅ C ₁ 2.5G 7/6
Chroma	H ₁ V ₁ C ₂ 2.5G 5/7	H ₁ V ₁ C ₃ 2.5G 5/8	H ₁ V ₁ C ₄ 2.5G 5/9	H ₁ V ₁ C ₅ 2.5G 5/10
H + V	H ₂ V ₂ C ₁ 1.25G 5.5/6	H ₃ V ₃ C ₁ 10GY 6/6	H ₄ V ₄ C ₁ 8.75GY 6.5/6	H ₅ V ₅ C ₁ 7.5GY 7/6
V + C	H ₁ V ₂ C ₂ 2.5G 5.5/7	H ₁ V ₃ C ₃ 2.5G 6/8	H ₁ V ₄ C ₄ 2.5G 6.5/9	H ₁ V ₅ C ₅ 2.5G 7/10
H + C	H ₂ V ₁ C ₂ 1.25G 5/7	H ₃ V ₁ C ₃ .20G 5/8	H ₄ V ₁ C ₄ 9.25GY 5/9	H ₅ V ₁ C ₅ 8.45GY 5/10
H + V + C	H ₂ V ₂ C ₂ 1.25G 5.5/7	H ₃ V ₃ C ₃ .20G 6/8	H ₄ V ₄ C ₄ 9.25GY 6.5/9	H ₅ V ₅ C ₅ 8.45GY 7/10

Fig. 1. Percentage of judgments like the Upper Standard as a function of Colors and Steps. This plot includes each of the stimuli listed in Table 1.

Results

A preliminary analysis of variance of the critical trial data indicated that the main effects of *Colors* and *Steps* and the first order interaction *Colors* by *Steps* were highly significant ($p < .01$). No other effect or interaction was significant.

Scheffé's (1953) test for multiple comparisons, using the 99 percent confidence level, was employed to make individual comparisons within the main effect of *Colors*. The cue of Value was responded to significantly more often than Hue, and Hue significantly more than Chroma. The combination of Hue and Value was a better cue than Value alone; and Hue, Value, and Chroma combined provided the best cue.

Figure 1 is a graph of the *Colors* by *Steps* interaction. Steps from the Lower Standard form the abscissa, and percentage judged like the Upper Standard, the ordinate. There are slight differences in performance at the first step of each attribute and these differences increase and become reliable at succeeding steps. This is consistent, of course, with the significant term, *Colors* by *Steps*.

Value was obviously the dominant cue, but cue dominance did not preclude additivity, i.e., Hue and Value together provided a better cue than Hue or Value separately in spite of the dominance of Value over

Hue. The apparent superiority of the cue of Value over the combination of Value and Chroma was not reliable. These relationships were stable over time and were evident for individual Ss, thus not artifacts of grouping data.

Discussion

Miles (1965) suggested that color might be discriminated easily because it has three attributes. This study indicated that these three attributes (Hue, Value, and Chroma) were used additively. Chroma was an ineffective cue except when all three cues varied together. However, in an unpublished study, the present investigators found that when oddity problems could be solved for either color or tilt, monkeys chose tilt significantly more often when its Chroma was high than when it was low.

Meyer et al (1965) indicated that balance of the potencies of cues was critical to their summation. Studies which reported that cue dominance precluded additivity used unlike dimensions such as form, size, and color. In contrast, equal cue potency may not be critical for like dimensions, and the S may treat the three dimensions of color as a single attribute. In the present study, anyway, monkeys were able to utilize more than just the prepotent information in making a discrimination.

References

- Draper, W. A. Cue dominance in oddity discrimination by rhesus monkeys. *J. comp. physiol. Psychol.*, 1965, 60, 140-141.
- Judd, D. B. *Color in business science and industry*. New York: Wiley & Sons, 1952.
- Lashley, K. S. The mechanism of vision. XV. Preliminary studies of the rat's capacity for detail vision. *J. gen. Psychol.*, 1938, 18, 123-193.
- Meyer, D. R., Treichler, R. R., & Meyer, P. M. Discrete training techniques and stimulus variables. In A. M. Schrier, H. F. Harlow and F. Stollnitz (Eds.), *Behavior of nonhuman primates; modern research trends*. New York: Academic Press, 1965.
- Miles, R. C. Learning sets in primates. In A. M. Schrier, H. F. Harlow and F. Stollnitz (Eds.), *Behavior of nonhuman primates; modern research trends*. New York: Academic Press, 1965.
- Scheffé, H. A. A method for judging all possible contrasts in the analysis of variance. *Biometrika*, 1953, 40, 87-104.
- Warren, J. M. Perceptual dominance in discrimination learning by monkeys. *J. comp. physiol. Psychol.*, 1954, 47, 290-292.

Notes

1. This investigation was supported by U. S. Public Health Service Research Grant MH-07147-03, Institute of Mental Health. The first author was a NASA predoctoral research fellow.
2. The Munsell notation is written Hue Value/Chroma. The formula used in computing color difference between two Munsell notations was: $I = C/5 (2\Delta H) + 6\Delta V + 3\Delta C$. C equals the Chroma of the first color and ΔH , ΔV , and ΔC equal Hue, Value, and Chroma differences respectively.