Published in final edited form as:
Percept Mot Skills. 2003 December ; 97(3 Pt 2): 1038–1042.

Focal Colors and Unique Hues

Eriko Miyahara
Department of Psychology, California State University, Fullerton

Summary

The purpose of this study was to empirically investigate the extent to which focal colors and unique hues are related for red, green, blue, and yellow. Forty young adults were asked to pick focal colors and unique hues from 100 color patches printed on white paper. The saturation was varied in four levels. The results showed that the mean focal colors and the mean unique hues were almost identical for all of the four color terms investigated.

Keywords

color perception; focal color; unique hue; psychophysics

Focal Colors and Unique Hues

Eleven basic color terms (purple, blue, green, yellow, orange, red, pink, brown, white, gray, black) are known to be prevalent among various languages. These basic colors are general and salient (Berlin & Kay, 1969). Berlin & Kay prepared a rectangular array of Munsell color chips and asked informants to choose a “focal color” i.e., the best example of each color. The focal colors have been traditionally measured with Munsell color chips at maximum saturation. The informants were tested in their native language, including 20 different languages. The chosen focal color chips for each basic color term were narrowly clustered regardless of the language the informant spoke. This lead to the supposition of universality of basic color terms and their focal colors.

On the other hand, unique hues possess another line of history beginning with the opponent-process theory (Hurvich & Jameson, 1957; Hering, 1964) in which two chromatic (red-green and blue-yellow) and one achromatic (black-white) mechanisms are postulated. A unique hue is defined as a pure color without any tint of the other colors. The equilibrium point of the chromatic mechanism brings about the sensation of a unique hue. The equilibrium point of the red-green mechanism leads to either unique blue or unique yellow. The equilibrium point of the blue-yellow mechanism leads to unique red or unique green. Unique hues have been extensively measured with printed color charts (Hard & Sivik, 1981). Yet individual differences in unique hues to investigate underlying visual mechanisms have been traditionally measured by monochromatic lights with some recent studies involving the stimuli presented on a CRT display of lower saturation (DeValois, DeValois, Switkes, & Mahon, 1997; Webster, Miyahara, Malkoc, & Raker, 2000).

Although both focal colors and unique hues have been investigated extensively by numerous researchers, there has not been any study to investigate a linkage between these two similar concepts with identical stimuli. McDaniel (1972) measured observers’ focal colors on Munsell color chips, matched to the spectral lights, then compared them to the observers’ unique hues

Please address correspondence to: Eriko Miyahara, Ph.D., Department of Psychology, California State University, Fullerton, 800 N. State College Blvd., Fullerton, CA 92834-6846.

measured with monochromatic lights. Based on the results, McDaniel concluded that focal colors and unique hues are essentially the same (Wooten & Miller, 1997). Webster, Webster, Bharadwaj, Verma, Jaikumar, & Madan (2002) measured focal colors and unique hues from the same sets of observers. Yet they used separate sheets of printed color stimuli to measure focal colors and unique hues because they were interested in variation patterns among individuals and groups, rather than the identity of focal colors and unique hues.

In the current study, we asked 40 observers to choose four focal colors and four unique hues (red, green, blue, and yellow) from the same sets of 100 color patches. Each sheet contained patches of a fixed saturation. We used four sheets of stimuli with various levels of saturation.

Methods

Forty college students who were enrolled in an introductory psychology course participated in the study voluntarily for extra credit. Upon completion of the survey, the participant was screened for color vision defects by Ishihara Pseudoisochromatic Color Plates. Forty participants completed the survey and did not misread any Ishihara Plates.

The color stimuli were printed on a letter-size Kodak Premium Inkjet Paper (reflectance 86%) with a Hewlett Packard DeskJet 1220C printer. Each sheet consisted of 100 color patches with varied hue. The stimulus colors were created using the Color Picker function in Microsoft PowerPoint, an application in Microsoft Office 2001. With the HLS Picker in which the colors are specified by hue, saturation, and lightness, lightness was kept at 50 (middle level) for all the stimuli. In a color circle of 0° to 359° (360° = 0°), 100 hue angles were chosen as follows. Firstly, 90 hue angles were picked beginning at 0° with four-degree interval. Secondly, between the hue angles of 48° to 68° and of 348° to 8°, the hue angle was changed in two-degree interval to create ten more stimuli. This was to ensure that yellow and red regions have visually small enough changes of hue so that the participant could choose appropriate color patches without compromise. These 100 color patches were 1cm square each, aligned in a 20 x 5 matrix on a sheet of paper in the order of hue angle. Black integers 1 to 100 were printed under each color patch to indicate the color patch number. A sheet contained 100 color patches with saturation of 100, 60, 40, or 20 %. In order to eliminate the cue by the patch number, three versions for each saturation were created; the patch matrix began with either 260°, 280°, 300° in hue angles. The beginning patch hue angle was randomized for each saturation across the participants. The color patches were calibrated by a GretagMacbeth Spectrolino Spectrophotometer.

The protocol was initiated with the experimenter's explanation of the three dimensions of colors: hue, saturation, and lightness. Then the concepts of focal color and unique hue were introduced. They were also defined in the data sheet for the participant. The definition of a focal color was "The best example by the color name. The typical color. Universal all across different languages. The definition of a unique hue was "A pure color that does not contain a tint of any other color. For example, unique yellow is the yellow that is neither greenish nor reddish." The experimenter did not mention whether those two colors were presumed similar or different. The participant looked at a sheet of 100 color patches with a fixed saturation at a time in a predetermined order. For each sheet, he or she chose the color patch for focal red, focal green, focal blue, focal yellow, unique red, unique green, unique blue, and unique yellow and wrote the color patch number of choice in the appropriate box on the data sheet. The order of saturation that the participant observed was randomized across the participants.

Results and Discussion

The mean focal colors and the mean unique hues are shown by hue angle in Table 1. Paired *t* tests were performed to see whether there is a significant difference between a focal color and unique hue for each hue (red, green, blue, yellow) and each saturation (20, 40, 60, 100 %). With an α level of .05, the mean focal color and the mean unique hue were significantly different only for green at saturation 20 % ($t = 2.193$, $df = 39$, $p = .034$). The results of *t* tests for all the other combinations of color and saturation were not significant. Figure 1 shows the CIE chromaticity coordinates of mean focal color loci and mean unique hue loci. The error bars indicate standard deviations. The solid circles connected with the solid line are focal color loci. The open triangles connected with the dotted line are unique hue loci. The cross indicates the coordinates of the white paper surface used in the survey. For each hue, the data points are located from closest to the white point toward the spectrum locus, in the order of saturation 20, 40, 60, and 100 %. The unique hue loci are comparable to the results of former studies except for unique yellow. Unique yellow loci usually show a straight line in the chromaticity coordinates (Billmeyer Jr. & Bencuya, 1987;Burns, Elsner, Pokorny, & Smith, 1984;Larimer, Krantz, & Cicerone, 1974). Despite this nonlinearity of the unique yellow loci obtained in the current study, focal color and unique hue loci for the four color terms almost overlap with each other as shown in Figure 1.

This high correspondence between focal colors and unique hues is interesting considering the fact that individual participants did not necessarily choose exactly the same color patch for a given focal color and the corresponding unique hue. The incidence in which a participant chose the same patch for a focal color and the corresponding unique hue occurred 183 times overall, or 28.6% of all the combinations. In the remaining choices, the participants chose similar yet different patches. The participants in this study were naïve to the concepts of focal colors and unique hues. They were not informed whether focal colors and unique hues were considered identical or not to avoid a possible introduction of bias. From our results, we can state that focal colors and unique hues are very similar on an individual basis, and that they are almost identical when represented as group data.

The purpose of this study was to measure focal colors and unique hues from the same participants using identical stimuli. Traditionally, focal colors and unique hues have been measured separately with frequently different stimuli. McDaniel (1972) conducted an indirect linking study and concluded that they are essentially the same. Generally, scientists seem to agree with this view (Wooten & Miller, 1997). The results of the current study directly indicate that focal colors and unique hues are indeed very similar concepts when the data collected with identical color patches are interpreted as a group.

References

Berlin, B., & Kay, P. (1969) *Basic color terms: Their universality and evolution* Berkeley, CA: Univer. of California Press.

Billmeyer FW Jr, Bencuya AK. Interrelation of the Natural Color System and the Munsell Color Order System. Color Research and Application 1987;12:243–255.

Burns SA, Elsner AE, Pokorny J, Smith VC. The Abney Effect: chromaticity coordinates of unique and other constant hues. Vision Research 1984;24:479–489. [PubMed: 6740967]

DeValois RL, DeValois KK, Switkes E, Mahon L. Hue scaling of isoluminant and cone-specific lights. Vision Research 1997;37:885–897. [PubMed: 9156186]

Hard A, Sivik L. NCS-Natural Color System: a Swedish standard for color notation. Color Research and Application 1981;6:129–138.

Hering, E. (1964) *Outlines of a theory of the light sense* (L. M. Hurvich & D. Jameson, Transl.). Cambridge, MA: Harvard Univer. Press.

Hurvich LM, Jameson D. An opponent-process theory of color vision. Psychological Review 1957;6:384–404. [PubMed: 13505974]

Larimer J, Krantz DH, Cicerone CM. Opponent-process additivity -- I. Red/green equilibria. Vision Research 1974;14:1127–1140. [PubMed: 4428619]

McDaniel, C. K. (1972) *Hue perception and hue naming.* Unpublished BA thesis, Harvard Univer., Cambridge, MA.

Webster MA, Miyahara E, Malkoc G, Raker VE. Variations in normal color vision. II. Unique hues. Journal of the Optical Society of America A 2000;17:1545–1555.

Webster MA, Webster SM, Bharadwaj S, Verma R, Jaikumar J, Madan G, et al. Variations in normal color vision. III. Unique hues in Indian and United States observers. Journal of the Optical Society of America A 2002;19:1951–1962.

Wooten, B., & Miller, D. (1997) The psychophysics of color. In C. L. Hardin & L. Maffi (Eds.), *Color categories in thought and language* Cambridge, UK: Cambridge Univer. Press. Pp. 59–88.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

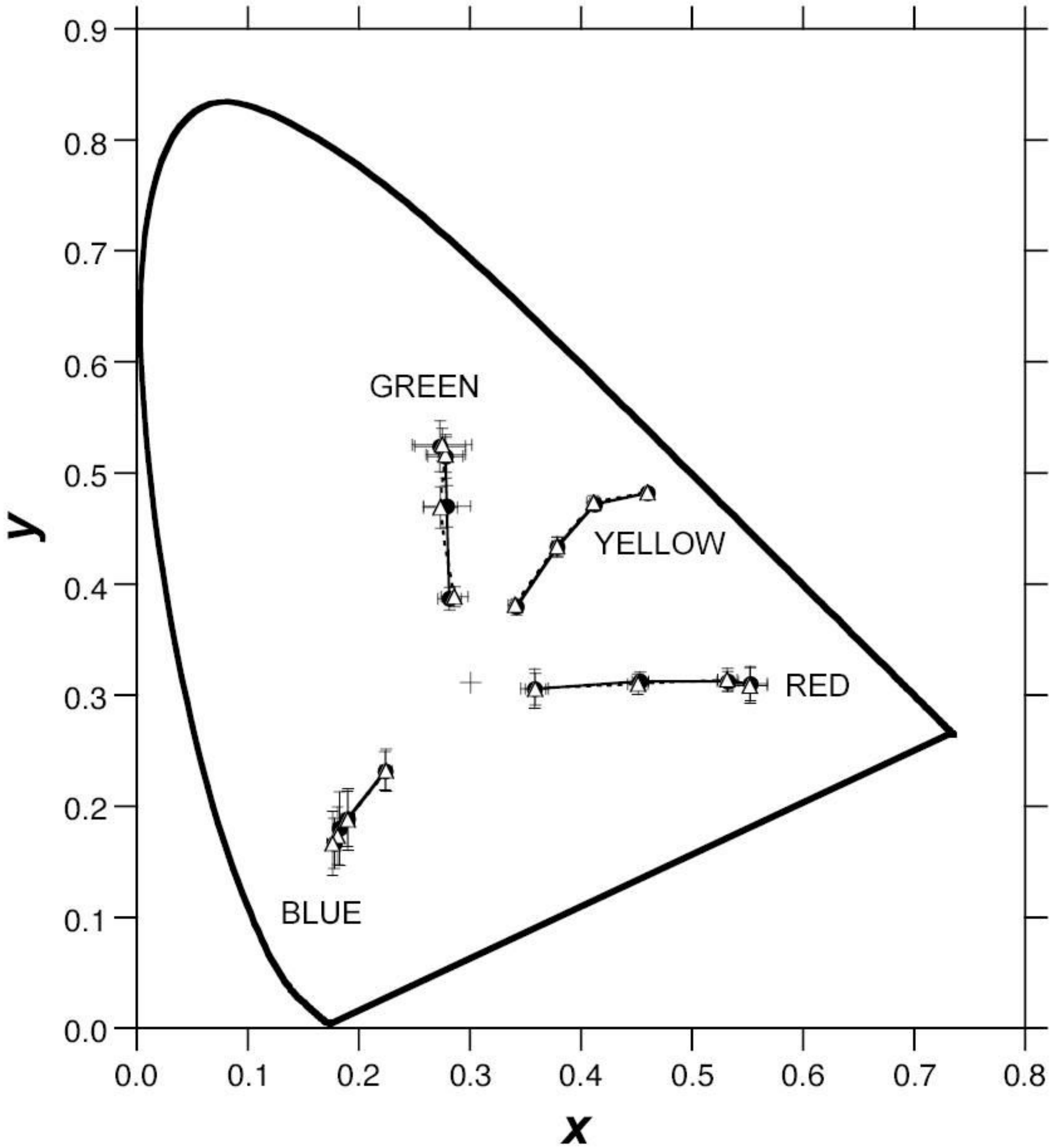

Figure 1.

The CIE chromaticity coordinates of mean focal color loci and mean unique hue loci. The error bars indicate standard deviations. The solid circles connected with the solid line are focal color loci. The open triangles connected with the dotted line are unique hue loci. The cross indicates the coordinates of the white paper surface used in the survey.

Table 1

Mean focal colors and mean unique hues expressed in hue angles.

		Red		Green		Blue		Yellow	
	Saturation (%)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Focal Color	20	356.1	13.1	118.3	10.8	225.1	13.1	58.2	7.4
	40	358.5	3.9	116.6	13.0	224.7	13.3	58.6	5.6
	60	357.3	4.3	120.8	10.3	220.7	16.6	59.7	3.2
	100	353.7	9.7	128.3	14.6	219.7	13.7	57.3	2.2
Unique Hue	20	356.5	10.3	113.6	12.0	226.0	15.3	60.3	7.1
	40	357.3	4.2	119.9	9.9	225.3	14.6	58.9	4.9
	60	357.9	4.7	120.9	10.3	222.6	13.1	60.7	3.8
	100	352.8	10.1	128.0	15.1	219.5	18.4	58.0	2.1