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Title: Equal Contrast Tint Progressions for Computer Cartography.

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A psychophysical bisectioning experiment was performed to evaluate equal steps within tint progressions on a high resolution graphics terminal. In the bisectioning experiment each respondent partitioned a tint progression by interactively defining colors that were perceptually equidistant between two previously defined colors. Twenty test subjects performed the test on the hues of red, blue and green. Controlled replications allowed for a controlled experimental design within subjects. Viewing angle, viewing distance and lighting also were controlled to reduce experimental error. Physical color (CIE 1931) was used to define a tint variable which was a transformation of luminanace and the tristimulus variables. The tint variable was defined by principal component analysis based on the color coordinates. A psychophysical relationship between the tint variable and perceptual classes was examined. The results from this

research indicated that tint is a nonlinear psychophysical function of color's physical attributes.

Equal Contrast Tint Progressions for Computer Cartography

by

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CHAPTER 1. INTRODUCTION

Cartography, the study of maps and the mapping process as a form of communication, is concerned with map production and design theory. Cartography is a diverse field with many areas of research including computer-assisted cartography, remote sensing, map projections and cartographic design.

Maps are utilized for academic research, professional decision making, navigation and many other purposes. As analytical tools, maps can be used in planning and policy implementation in resource planning, civil engineering and geological engineering and other professions.

The cartographer's primary task when creating a thematic map of statistical data is to give an accurate representation of the spatial distribution to the map reader. Typically, the symbolism used for the statistical data portrays as much quantitative information as possible without detracting from the overall interpretation of the map. Quantitative data are communicated from the map image to the map reader so as to faithfully represent the spatial distribution on the map. A primary focus of cartographic design is to evaluate the relationship between perceptual characteristics of the map symbols and the phenomena they represent.

Color, a powerful tool of graphic communication, assists the cartographer in the design of many types of maps. Color can increase detail, add visual interest, assist in the discrimination of numerous variables, and contribute to perceptual associations that enhance the design of a map. Color progressions can assist the cartographer in the representation of detailed quantitative information while retaining a visually pleasing map design. These progressions should be presented so that perceptual differences are similar and can be categorized. This can assist in the interpretation of spatial data on a map by providing effective perceptual categorization of physical map data. The primary objective of this research is to examine the psychophysical characteristics and use of color tint progressions in computer cartography. Tint is a progression from a white to a fully saturated color such as red, green or blue.

This research specifically examines two properties of tint progressions: 1) the mathematical relationships between computer specified color and physically based color, and 2) the mathematical relationship between perceptual magnitudes and physical and computer based color. The paper is organized into three subsequent sections: literature review (examining relevant cartographic and color research), methods (experimental design of the perceptual test and data manipulation), results (the graphical and statistical results from the research) and a discussion of the results.

CHAPTER 2. LITERATURE REVIEW

The understanding of cartographic design research and color research is important to the cartographer examining tint progressions. Cartographic design research enables the evaluation of the map as a communicative tool. An examination of this literature can assist in planning cartographic research. Color research is an interdisciplinary science consisting of colorimetrics, psychophysics, and computer science. These different topical areas have addressed various color specification systems and research methodologies.

Cartographic Design Research

Recent cartographic design research has examined the map as a communication tool for representing spatial information. This research has evaluated the map-human interface in light of cartographic communication theory, which treats the entire map as a graphic communication tool, and has focused on the the systematic relationships between the map user, the map and the cartographer in an abstract form. Cartographic design research has tended to examine individual components of the map as communication attributes. Design research is a component of communication theory underlying the interpretation of a map image.

Robinson's The Look of Maps (1952) is the first published work to examine cartography from a theoretical approach. Robinson viewed the map as a dynamic communication system which should be examined with psychological methodologies. Robinson initiated the transfer of information between the map and the map user as a research topic. By examining this the cartographer could improve the reader's interpretation of the map. Robinson promoted design research and commented on its absence in early cartographic literature:

> Most of the writers on cartography have touched upon this subject [visual relationships], usually implicitly, rarely directly, and visual relationships are generally considered to be artistic or psychological components which cannot be avoided, but which should be guarded against (Robinson 1952, p. 21).

Cartography as a theoretical science evolved largely under the influence of a few key figures. Robinson's initial work sparked the beginning of cartographic design research which profoundly influenced theoretical cartography. In the late 1940's Robinson completed his "unorthodox " dissertation at Ohio State University (Robinson 1952, preface). This work, later published in 1952 as the Look of Maps, was a theoretical examination of the map image and its specific components. This study provided the foundation for the design research studies of the 1960's and 1970's.

Cartographic Communication

Cartographers have examined the mental processing of the map image by modeling the relationships among the map, the map user, and the map maker. These models, the foundations of cartographic communication theory, depict the cognitive processing of a map. Olson (1983) states:

> Models of cartographic communication are indeed focused on the transmission of information between beings (albeit in a rather stringent fashion), but we [cartographers] seem also to apply the term to any intellectual questions concerned with map symbolism, map users, the psychology of maps, map meaning, and so on. I suspect we are guilty of trying to cram onto one concept rather more than is productive (Olson 1983, p. 260).

Taylor (1983) gives a historical overview of cartographic communication research in his excellent anthology on progress in contemporary map design. Many researchers have addressed communication theory and the mental processing of maps. An early contributor, Board (1967) asserted that the map image can be modeled as a system that transfers information from cartographer to map user (Figure 1). This transfer is complicated by many factors, such as past map use experience. Communication models have been constructed to illustrate the processing of map images. Board's model is an excellent example of how cognitive and perceptual psychology relate to cartography. The model represents the cognitive process by which the map reader interprets the mental and physical map. By understanding this process, the cartographer can better theorize how to maximize map information transfer to the user and create more effective map designs.

Robinson and Petchenik (1976) note in their discussion of the cognitive processes that visual cognition is significant in cartographic perception. Drawing from the work of Neisser, they stated:

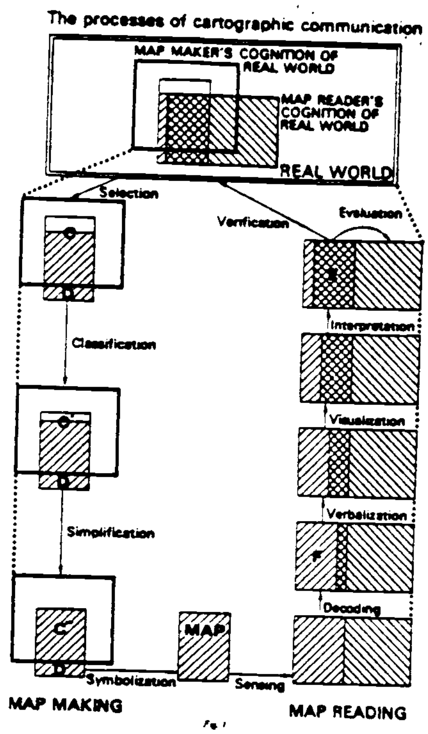


Figure 1. Board's Communication Model. Source: Board 1973.

> Many of the phenomena and objects commonly put on maps are visible at the earth's surface and our knowledge of them is naturally affected by the nature of the human visual processing. More important, all such phenomena, even those that are invisible in the milieu (e.g., population density), are converted to visual forms on a map, and therefore an understanding of visual cognition is one of value in predicting the potential of the map percipient for comprehending the map. (Robinson and Petchenik 1976, p. 68).

Cartographers have drawn from many disciplines when performing research related to communcation theory. Experimental psychology has had a major influence on contemporary map perception studies. Psychologists, as well as cartographers and geographers, have been interested in the mental processing of geographic data, and/or the visual perception of spatial distributions. Many psychological tests have addressed the misinterpretation of mental maps that are visually encoded. Stevens and Coupe (1978) demonstrated how distortions were created in one's judgment of spatial relationships between political and geographical locations. They hypothesized that geographical data are stored hierarchically in the mind. Other studies have examined the relationship of navigation to spatial setting

(Thorndyke and Stasz 1980). These studies tend to be of limited value to the cartographer who is interested in cognitive processing and the perceptual nature of the map image, not the long term storage of spatial data. If cartographers can determine how the viewer processes the information, they can plan the map design so the cartographic display is both quantitative and aesthetically pleasing.

Design research attempts to determine how information is visually acquired and to find existing perceptual-cognitive relationships. The map is unlike many other graphic representations; it has connotative associations which are characteristic of spatial distributions. Symbolization and geographical reference systems have been incorporated into the mapping process for centuries. Since maps convey spatial information, they are distinctively different from graphics or words.

Certain mapping methods and attributes have been examined by psychophysical testing in order to understand the perceptual attributes of a map. These studies have examined symbol perception, typography, orientation, map complexity and other cartographic components.

Psychophysical Cartographic Testing

Psychophysical studies in cartography have been performed on various mapping methods since the late 1950's. Psychophysical tests have been conducted to create a set of perceptual guidelines to explain the apparent perceptual deviations of physical stimuli. These research methodologies are focused on one map component, with the goal of maximizing the communication capability of the specific component.

Psychophysics is concerned with the perceptual processing of stimuli and with quantifiable relationships between the physical variable and its perceptual magnitude. Stevens (1975) indicated that the psychophysical functions for loudness, brightness, pain and other responses are power functions of the perception and the physical stimulus.

Testing methodologies commonly utilized in cartographic research include magnitude estimation, ratio scaling, magnitude comparison, and partitioning (see Table 1 for examples). The psychophysical methodology employed in design research will have a profound impact on the result (Chang 1980). The primary goal of each method

Table 1. Cartographic psychophysical testing methodologies with typical questions or task.

Method	Typical Question/task	Study
Magnitude estimation	How large do you think it is?	Chang (1980)
Ratio scaling	Which one is twice as large?	Flannery (1971)
Magnitude comparision	Which one is the same size?	Shortridge (1979)
Partitioning	Divide up equally	Kimerling (1975)

the result (Chang 1980). The primary goal of each method is different and will yield significantly different results. The use of a map is complex and varies among map users. Cartographic experimentation is not suited to one pyschophysical testing method because estimations and comparisons occur simultaneously when interpreting a map.

Over the past twenty years studies by cartographers have led to the development of different power functions relating the perceptual and physical attributes through which the sizes of graduated symbols are perceived on a map. Most of these studies have examined symbols found primarily on small scale thematic maps. The significance of these studies and their empirical conclusions is presently being debated. Direct comparisons between the psychophysical studies addressing symbolization is complex due to different experimental designs. Chang (1980) discusses the implementation of results from ratio scaling, magnitude estimation and other psychophysical methodologies employed in past cartographic point symbol research. Chang indicated that the derived various power functions relating perceptual and physical attributes were primarily due to different experimental designs and objectives.

External factors, such as optical illusions, can alter the whole map design. The map image must be viewed as a multi-symbol model containing many dependent symbols which interact. Map title, content and legend design all affect each other, and can alter the perception of the entire map.

Olson (1983) has commented on the prospects for future research:

> The very trend away from the psychophysical and towards the cognitive study with maps is tied to the rethinking of map use tasks, and while psychophysical studies can be useful for deriving certain guidelines for map design, it is the more cognitive study that is attracting interest in cartography now and will be of more interest in the immediate future to research in this area [cartographic design] (Olson 1983, p. 278).

Olson indicates that psychophysical studies will be related to automation in the future and specifically related to the construction of design algorithms, which require quantitative or logical design guidelines.

The aim of psychophysical research in cartography is to understand human perception of map components. Cartographic research should contain psychological methodologies which can address perceptual and cognitive processes. The cartographic use of color to enhance the design effectiveness of a map by classifying quantitative associations is an important area of research. Results from perceptual research relating to the cartographic use of color can assist the cartographer in the design of color maps.

Color Research

The importance of color in cartography is apparent in design research and production cartography. Color is utilized in map design as a means of figure-ground enhancement and to improve the visualization of magnitude progressions on choroplethic and dasyimetric maps as well as on recently studied bivariate maps (Olson 1981; Eyton 1984). Bivariate maps incorporate statistically correlated data in a cartographic setting, portraying complex information concerning the spatial distribution. Robinson (1980; 1967) emphasized the importance of color in his rebuttal to a criticism of the necessity for design research in cartography:

> Research does not in any way inhibit skill and excellence. On the contrary, its aim is

> to provide more information with which the skillful designer may work. Artists can, indeed, be involved in discovering facts useful in cartographic design, but it will be done through research, not by a pronouncement by a "specialist in perception." A case in point is the equal-value gray scale in the Munsell color system, which is of considerable utility to cartographic designers. A. H. Munsell was an artist, but he evolved it by painstaking research involving a considerable program of testing (Robinson 1980, p. 78).

Color science is a combination of two interrelated disciplines: psychology and colorimetry. Colorimetry is primarily concerned with the technical properties of color. The optical sciences have developed color specification systems based on the physical properties of color. Psychologists have examined the discrimination and identification of color based on one of several color specification systems.

Color research is performed in many disciplines because of its wide appplications. Color is also used in soil science, food science, textile technology and engineering for the rapid classification and discrimination of many physical variables. The term "color" can have many different definitions that relate to both its physical and perceptual attributes.

The visible color spectrum (wavelengths ranging from approximately 400 to 700 nanometers) can be divided into violet, blue, green, yellow, orange and red. Other colors can be created by combinations of primary colors at specific wavelengths. Two systems for defining color are the additive and subtractive primary color systems. Nearly all colors can be created by mixing additive (red, green and blue) and/or subtractive primary colors (cyan, magenta and yellow). Reflective color is created when subtractive primary pigments are combined on a white surface and illuminated by white light.

Colorimetry

Various colorimetric methodologies were developed in the 19th and 20th centuries for the classification of color. The Commissopn Internationale de l'Eclairage (CIE), Ostwald, Munsell, MacAdams and Red-Green-Blue (RGB) systems are just a few of the common color specification systems utilized in graphic design, cartography and the computer industry (Table 2).

Table 2. Common colorimetric specification systems and attributes.

<u>Physical Based Systems</u>

Major systems	Color Attributes
CIE	Y Luminance x Chromaticity y Chromaticity
HSI	Hue Saturation Intensity
RGB	Red Green Blue

<u>Perceptual (Uniform) Systems</u>

Major Systems	Color Attributes
Munsell	Hue Value Chroma
$L^*u^*v^*$	L^* - Lightness (transformed CIE) u^* - Chromaticity Variate from G to R v^* - Chromaticity Variate from B to Y
$L^*a^*b^*$	L^* - Lightness (transformed CIE) u^* - Chromaticity Variate from G to R v^* - Chromaticity Variate from B to Y
Ostwald	Hues and Tints
MacAdams	CIE derived

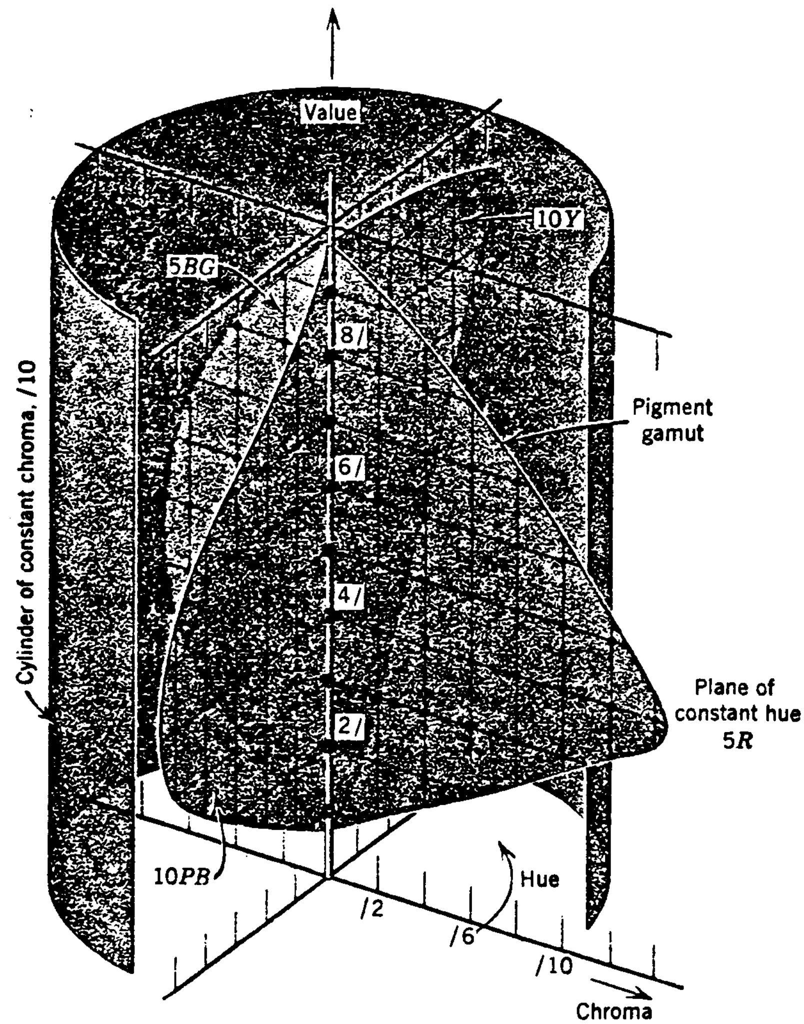
Color has basic properties that can be expressed in many different colorimetric specification systems. The CIE 1931 color space is a physically based color system based on luminance and tristimulus color. Luminance (Y) is the amount of reflecting grayness in a color. The tristimulus values (x,y) are determined by percentages of the combined imaginary primaries of red, green and blue. The CIE color system is based on a three-dimensional color space (Y,x,y) which requires the mixing of imaginary hues and the luminance of the color. The CIE tristimulus variables (x,y) are based on chromaticity, which is the degree of purity of a color as opposed to the amount of grayness, or achromatic value, in a color. Color has both achromatic and chromatic properties. The CIE color space is based on physical color properties and not on perceptual aspects. Physical color is based on physically measured colorimetric specifications whereas perceptual color is based on perceptual properties.

Uniform color systems are colorimetric specification systems which have inherent perceptual spacing between colors in the color space. The three - dimensional aspects of physical color (luminance and chromaticity) are transformed, so the perceptual dimensions can be mentally processed with equal perceptual spacing among colors. Each color attribute is spaced uniformly in accordance with the perception of a normal observer (Wyszecki and Stiles 1967).

The Munsell System, the most commonly used perceptual color system in the United States, is a uniform color system based on perceptual color space (MacAdam 1981). The Munsell color system has three components: hue, value and chroma. Hue corresponds to the dominant wavelength of the color, such as red, green or blue. Value is the amount of grayness in the color, and chroma is the pureness of the color, such as a light blue or deep blue.

Saturation is another important dimension of color. Saturation is defined by Wyszecki and Stiles (1982, p.360) as "the attribute of a visual sensation which permits a judgment to be made of the degree to which a chromatic stimulus differs from an achromatic stimulus regardless of brightness [value]". This is similar to a chroma except that value is held constant.

The Munsell system can be described in a graphical three-dimensional color space as being basically cylindrical (Figure 2). The actual cylindrical shape is



Schematic diagram of the Munsell color solid showing four planes of constant Munsell hue (5*R*, 10*Y*, 5*BG*, and 10*PB*) and a cylinder representing constant Munsell chroma (/10). Planes of constant hue intersect at the Munsell value axis, which also is the common axis of all cylinders of constant Munsell chroma. Planes of constant Munsell value intersect this axis perpendicularly (from Judd and Wyszecki 1963).

Figure 2. Munsell color space with hue value and chroma represented as independent axes. Source: Wyszecki and Stiles 1982.

not symmetrical due to variation in chroma between the low and high value hues. This gamut does not fill the theoretical color cylinder completely.

Other common perceptually based uniform color systems are the $L^*u^*v^*$ and $L^*a^*b^*$. Tajima (1983) has indicated that these systems have potential for color classification in computer graphics. An advantage of $L^*u^*v^*$ and $L^*a^*b^*$ is that tranformation functions exist for conversion to the CIE system. These color systems also have functions allowing transformations into Munsell chroma values (Wyszecki and Stiles 1982).

The RGB color system is based on combinations of different intensities of red, green and blue. The RGB color system has the three dimensional shape of a cube (see Figure 3). Red, green and blue color intensities are independent of each other, representing orthogonal axes of the color cube. Different combinations of the color percentages will create different colors. An RGB

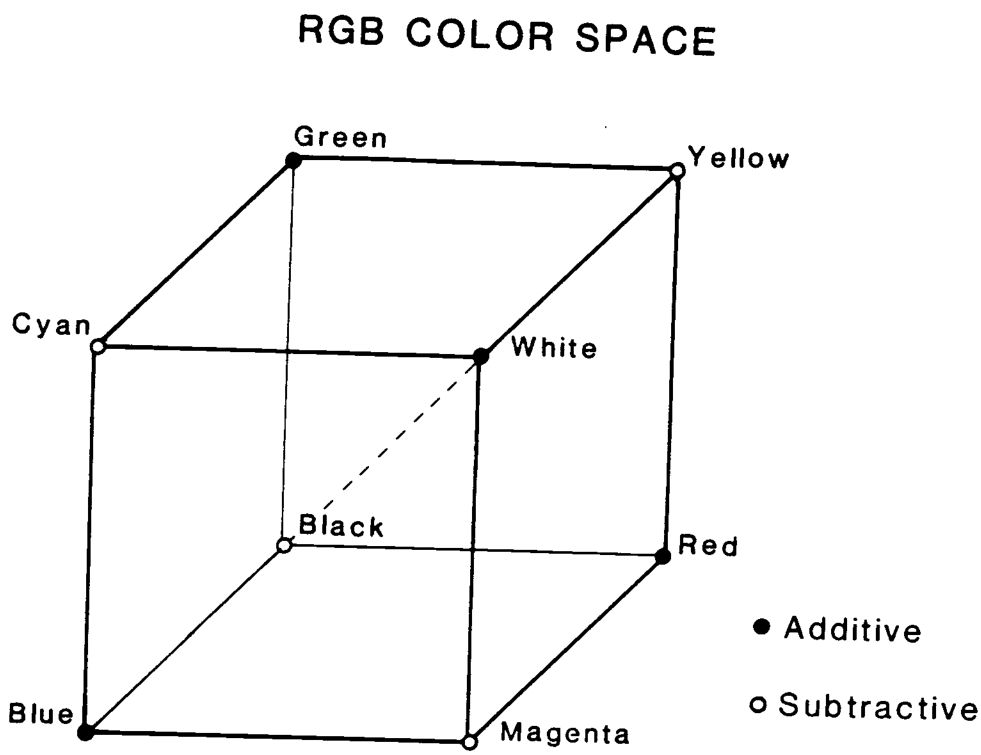


Figure 3. RGB three dimensional color space with additive and subtracttive primary colors at cube corners.

coordinate system is commonly implemented on automated equipment (computers) because of its simple mathematical properties. RGB identifiers in this system commonly range between 0 and 255. Over 16 million different color combinations could be formed, but the differentiation between similar combinations of colors is perceptually impossible.

Psychophsyical Color Research

Color research has primarily dealt with achromatic aspects of color. Achromatic color is the whiteness or blackness (value) of a color, whereas chromatic color is the mixing of hues to create others, commonly referred to as the colorfulness. Achromatic color is perceptually different from chromatic color. Achromatic color can be visualized as graytones. Opponent process theory has indicated that neurological differences may be occurring when color is perceptually processed (Varley 1980).[1] Psychological research has confirmed that color is processed so "that black and white differ from the paired-chromatic opponent colors" (Quinn, Wooten, and

Ludman 1985). This research indicates that some neurological cells are inhibited or excited based on whether the color is visualized with the chromatic or achromatic component. This indicates that achromatic and chromatic color may be processed differently.

Color distinction and discrimination are two different methodologies in psychophysics. Distinction refers to the processing of just-noticeable-differences (jnd), whereas discrimination refers to color differences that appear equal in magnitude. Jnd's are associated with color differences and are not as applicable to cartographic design research as discrimination. The large number of color combinations possible on modern computers promotes the incorporation of categorical classification of physical color. Incorporating uniform color space on computers could assist in the ergonometric design of hardware and software.

Many psychophysical testing methodologies presently exist (Stevens 1975; Jones 1974). Stevens (1974) noted that psychophysical functions relating physical variables to perceptual attributes follow a power function relationship. This indicates that physical variables at large magnitudes are not as perceptually different as at smaller magnitudes. Individual methods can produce distinctively different power functions. Stevens (1974) has noted that the exponent for the Munsell value is approximately 0.33 for partitioning experiments, whereas magnitude estimation produces an exponent of 1.2. Marks (1974) noted interval scales "typically" have smaller exponents than ratio scales. Interval scales are based on equi-distant spacing, such as obtained from a partitioning experiment. Ratio scales are obtianed from ratio scaling or magnitude estimation, where the respondent estimates a magnitude based on the symbolism. The method used in a psychophysical study will have a profound impact on the derived perceptual function.

In 1933, Godlove performed a psychophysical study similiar to Munsell's, examining one attribute of color, value, and its perceptual relationship to reflectance. Godlove arrived at conclusions similar to Munsell and noted the importance of incorporating the reflectance of the background into the experiment. Godlove concluded that due to differences in experimental design, the results of his study differed from those of his contemporaries.

Studies have continued to examine the psychophysical relationships of achromatic value to perceptual categories. Godlove's formula for achromatic color classification has been revised to increase precision and accuracy. Newhall (1940) proposed a high-order polynomial relating perceptual classes and physical graytones. Glasser et al. (1958) introduced a cube root function which defines the Munsell value, given reflectance changes, with a high degree of accuracy. These formulae are the foundations for describing uniform color spaces which can be incorporated in computer software to increase aesthetics in design.

Psychologists have examined psychophysical testing methodologies extensively since the 1940's. Disagreement has arisen concerning the best psychophysical methods for the testing of perceptual responses to physical stimuli (Weiss 1981). Historically, in psychology two functions have been related to the scaling of intensity changes: power functions (based on the work of S.S. Stevens) and logarithmic functions (based on the early work of Fechner). Stevens' power function has become the accepted basis for most intensity responses. Weiss (1981) has presented two issues concerning the power function: a) it can describe any subjective scale of intensity; and b) the usual statistical techniques may be inappropriate for the evaluation of nonlinear data such as would be predicted by either law. Regression must be evaluated carefully due to the small number of data points characteristic of many studies. Autocorrelation can introduce unwanted error and correlation can be misrepresented. Nonlinear analysis of variance can be used to evaluate inherent statistical problems.

Meyers (1982) noted that the statistical means of physical variable scales in psychophysical studies can be a major factor influencing results. The statistical mean in psychophysical research may not be a good measure of central tendency. Measuring many physical variables is not always linear and can have a profound effect on the formation of a power function relating the physical scale to a psychological measure. A typical example is the measurement of loudness by decibels. This measurement method is a logarithmic function and would bias the results because a statistical mean has assumptions of normality. Problems arise if the stimulus spacing is performed without recognition of the mathematical properties of the scale. Meyers states:

> If the psychophysical function truly is a power function, it would remain a power

> function regardless of which scale was used, insofar as they are power transformations of each other; the size of the exponent, however would be at the mercy of the stimulus measure used (Meyers 1982, p. 205).

This agrees with the graduated symbol studies in cartography, which derived differing power functions based on the implementation of magnitude scaling or ratio estimation.

In 1966, Panek and Stevens performed a perceptual study on the saturation of red. Three psychophysical testing methods were used: magnitude estimation, cross-modality comparisons, and category estimation. All three testing methods yielded similar results. The identification of the relationship between saturation and its perceptual magnitude indicate that small perceptually differences are a power function relating saturation to a perceptual scale. Indow and Stevens (1966) performed a study similar to Panek and Stevens (1966), examining the scaling of hue and saturation. This study provided insights into the evaluation of uniform color spaces. Three different psychophysical techniques were used: magnitude estimation, equisection partitioning, and jnd scaling. The relationship between saturation and perceptual magnitudes was determined to be a power function for all Deviation in the function for saturation can be seen between different hues (Figure 4). This deviation could be due to the small number of subjects (n=12) or to the measurement of luminance with a nonlinear scale (decibels - a logarithmic function). The methodologies used to derive the functions have drastically different objectives: discrimination, estimation or comparison.

In 1943 a group of prominent color scientists examined the spacing of the Munsell color space with mathematical techniques and experimentation (Newhall, Nickerson and Judd 1943). Tables and charts were published defining the Munsell color system in CIE coordinates. Conversions between the CIE standard coordinate system and the revised Munsell system were presented. Different backgrounds and experimental conditions were incorporated into their study. They note the complexity involved in the evaluation of color:

> The problem now seems more complicated than at first; and it may be that greater compromises with the ideal of perceptual uniformity have been made in order to secure a workable system than was anticipated (Newhall, Nickerson and Judd, 1943, p. 418).

Explicit and precise functions for perceptually categorizing color are not the goal of scientists examining color; rather ,they hope to establish general

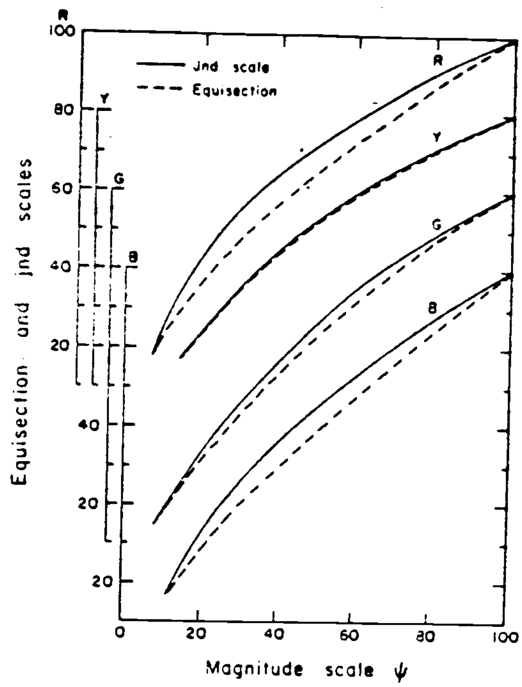


Figure 4. Scales of perceptual magnitude and physical measures of saturation. Source: Indow and Stevens (1966)

guidelines for the definition of uniform color space.

Research in color science has historically relied on intensive methodologies, such as magnitude estimation and ratio scaling. Magnitude estimation and ratio scaling are also the methods employed by cartographers evaluating the quantitative relationship between perceived size and actual size of point symbols.

Lozano (1977) performed a statistical analysis of several color difference formulae. The first group of test subjects subjectively evaluated lightness with hue and saturation remaining constant. The results of this test are presented in Table 3. The second group evaluated saturation while hue and lightness remained constant (Table 4). The correlations between the colors and the perceptual responses are significantly lower for the second group because the majority of the tested formulae were originally composed for value/lightness scales. The correlation between perceptual responses and physical color are similar and indicates the function may be similar between chroma/saturation and value/lightness.

Recent research in color science has addressed a new set of questions with new methodologies. A recently developed perceptual research method is the investigation

Table 3. Comparison of lightness functions (I). Source: Lozano, 1977.

Parameters of the regression line and values of the correlation coefficient of comparison between calculated color differences and subjective appraisal, ordered in decreasing value of r, for Group I (samples 1–97).

Formula	r	m	S_x	$S_x \cdot m$	$S_{x/y}$
Reilly Cube Root (E_1)	0.913	0.64	−13:43	8.59	−3.87
CIE $L^*a^*b^*$ (E_4)	0.911	0.32	−26 60	8.51	−3.89
ANLAB (E_4)	0.908	0.70	−12.21	8.55	−3.97
FMC-2 (E_3)	0.906	0.45	−19.15	8.62	−4.00
Hunter–Scofield (E_7)	0.906	0.61	−14.02	8.55	−4.00
Saunderson–Milner (E_{10})	0.897	3.14	−2.68	8.48	−4.17
FMC-1 (E_2)	0.883	0.35	−24.11	8.44	−4.43
Judd–Hunter (NBS) (E_6)	0.882	2.02	−4.14	8.36	−4.45
CIE $L^*u^*v^*$ (E_5)	0.852	0.57	−14.27	8.13	−4.95

Coefficient of regression:	r
Slope of the line of regression:	m
Standard deviation of the calculated data:	$S_x{}^2$
Standard deviation of x on y:	$S_{x/y}{}^2$.

Table 4. Comparison of lightness functions (II)
Source: Lozano, 1977.

Parameters of the regression line and values of the correlation coefficient of comparison between calculated color differences and subjective appraisal, ordered in decreasing value of *r*, for Group II (samples 98–193).

Formula	r	m	S_x	$S_x \cdot m$	$S_{x,y}$
Judd–Hunter (NBS) (E_6)	0.772	0.32	45.44	14.54	14.53
Hunter–Scofield (E_7)	0.766	0.51	34.40	17.54	14.72
Reilly Cube Root (E_1)	0.761	0.43	40.70	17.50	14.86
CIE $L^*a^*b^*$ (E_4)	0.760	0.32	83.04	26.57	14.87
ANLAB (E_9)	0.759	0.46	37.65	17.32	14.91
Saunderson–Milner (E_{10})	0.734	1.79	9.38	16.79	15.55
CIE $L^*u^*v^*$ (E_5)	0.729	0.32	52.48	16.79	15.66
MacAdam Geodesic Space (E_8)	0.704	0.26	62.45	16.24	16.26
FMC-2 (E_3)	0.682	0.19	84.36	16.03	16.73
FMC-1 (E_2)	0.621	0.20	71.22	14.24	17.94

Coefficient of regression:	r
Slope of the line of regression:	m
Standard deviation of the calculated data:	$S_x{}^2$
Standard deviation of x on y:	$S_{x/y}{}^2$.

of uniform color spaces by multidimensional scaling (MDS). MDS refers to a multivariate statistical technique for estimating the parameters in, and assessing the fit of, various spatial distance models for proximity data (Davidson 1983; Kruskal and Wish 1976). This method allows the experimenter to represent a statistical distribution in p-dimensional hyperspace. An MDS experiment evaluates the three-dimensional color space as a multivariate distribution. MDS perceptual color tests rely upon subjective simultaneous evaluations of hue, chroma and value differences between colors. Test subjects usually respond to a semantic differential test or to a categorical classification of similarity. These responses are evaluated by MDS techniques and the correlations are plotted, in a map form, in two or three dimensions. This is an indirect method of examining color, as opposed to direct psychophysical (intensive) methods.

The Munsell uniform color space was evaluated with MDS by Indow and Aoki (1983), Chang and Carrol (1980), and other color scientists. Historical psychophysical studies by Godlove, Newhall and others have transformed the three-dimensional color space into a univariate distribution.

This has been done by testing one attribute of color while holding the other two constant (Table 5). Multidimensional scaling evaluates all attributes of color simultaneously, and can be used as a perceptual color verification procedure because the spacing of all three color dimensions are evaluated simultaneously.

Indow and Aoki (1983) indicated that hue spacing in the Munsell system may not be uniform; e.g., spacing in the blues may not be equidistant. Marks (1974) has reviewed MDS studies related to the color space, and concludes that in many instances the obtained scale values "agree reasonably well with the Munsell notation" (p.371).

Chang and Carrol (1980) speculate from the evidence of an MDS test, that more than three dimensions of color space exist. Their research indicated that "this 7 ± 2 [dimensional] color space" is interrelated with its physical properties. This could be related to the psychological phenomena associated with color, such as simultaneous contrast, mach banding and brightness constancy. Chang and Carrol, as have many color researchers, incorporated many persons who had difficulties distinguishing colors (referred to as color deficients: propanopes, deuteranopes, proanomalous,

Table 5. Multidimensional scaling methodology in color science.

	Hue	Value	Chroma	Study
	Variable	Constant	Constant	Munsell (Original experiment)
	Constant	Variable	Constant	Godlove (1933)
	Constant	Constant	Variable	Panek and Stevens (1966)
MDS:	Variable	Variable	Variable	Indow and Aoki (1983)

deuteranomalous) into their research. Color researchers have also tested people who view colors normally (referred to as color normals: trichromates). Color normals mix three colors to create perceived colors, whereas color deficients mix one or two colors. The incorporation of different degrees of color blindness in color perception tests allows the color distribution to be viewed, theoretically, in a smaller dimensional space. This can be utilized to verify hypotheses concerning color normals.

Cartographic Color Research

Cartographic color research has focused on color as a aid to cartographic communication. Hue, value and chroma, as defined by Munsell's perceptually based color system, have been used extensively in map design. Hue has connotative associations that can create perceptual associations on a map (Robinson 1977). For example, blue can represent cool temperature or water and green can be used to denote vegetation lushness. Progressions of chroma or saturation within a hue can represent the magnitude range of a set of cartographic data. This can assist in the creation of maps that are aesthetically pleasing and present quantitative progressions clearly. Cuff (1972) has shown how value and chroma can be used effectively to represent quantitative progressions on maps.

Psychophysical aspects of the achromatic graytone scale have been examined in a non-cartographic setting. Studies by Williams (1958), Jenks and Knos (1961) and Stoessel (1972) examined the grayscale function, but due to differing experimental conditions, objectives and methodologies, results are not applicable to fine values that are implemented in color processing. Kimerling (1975) proposes a power function relating surface reflectance perceptual classes based on psychophysical experimentation. Other recent studies (e.g., Williamson 1982) had similar results but varied in the functions derived due to experimental (psychophysical) methodologies and the measurement of the physical stimuli. A complete presentation of graytone studies is presented in Kimerling (1985). His study indicates that magnitude estimation procedures may be effective for unclassed data, whereas partitioning methods are more effective for classed data.

Chromatic color research in cartography has been limited and mostly empirical. Cuff (1972) evaluated the use of color schemes and determined that chroma and value scales can effectively transmit a logical quantitative progression. Cuff recommends chroma progressions for most quantitative maps to represent magnitude changes.

Kimerling (1980) has examined the technical aspects of color specification in cartography. The difference between the CIE color space and the Munsell color space was examined with its application to process color tint screens. By understanding the transformation between these systems the cartographer can precisely specify the color for a map.

Cartographic researchers have advocated the use of perceptually uniform color spaces. Shellswell (1976) advocated the use of uniform color space in cartography, as have other cartographers (Robinson 1982). McGranaghan (1985) performed a study evaluating color associations for point symbols on computer cathode ray tubes. Empirical evidence has been found indicating that darker symbols are seen as representing larger magnitudes. McGranaghan's study can be used as a preliminary evaluation of the differences of luminance perception on cathode ray tubes.

Cartographers have debated the use of unclassed mapping techniques in the implementation of patterns and graytones (Dobson 1973; Tobler 1973; Peterson 1979). This directly relates to the formation of a uniform color space since the advent of automation in cartography has enabled the display of more data classes. Tobler (1973) has criticized the use of small numbers of classes (4 to 6) on choroplethic maps, and has encouraged the use of classless maps. If classes are implemented, Tobler recommends the use of 64 classes to maximize the quantitative representation. In rebuttal, Dobson (1973) noted the need to generalize data into classes so mental processing can be facilitated. Map use is normally related to nominal and ordinal tasks not requiring complex discriminations or comparisons. Dobson has summarized a major question in theoretical cartography by stating:

> The more important question revolves around balancing quantization error (a decreasing function of the number of classes) and perceptual error (an increasing function of the number of classes)(Dobson 1973, p. 359).

Muller (1979) and Peterson (1979) concluded, from a review of perceptual research, that large numbers of tones and patterns can not be distinguished on a map. Many colors are identifiable on a map, but color differentiation on a map is significantly more difficult than color discrimination.

Color Research on Cathode Ray Tubes

Color on cathode ray tubes (CRTs), a common medium of display on a computer, has properties different from reflected color. Color on CRTs is most often specified in the RGB color system, which is based on the additive mixing of red, green and blue light. The colors are created by controlling the voltage on the CRT screen which excite the RGB phosphors. Red, green and blue are specified based on wavelengths of color at 700 nanometers (nm), 546.1 nm, and 435.8 nm, respectively. Color on CRTs is emitted, whereas color on paper is reflected, and the properties of emitted and reflected color are distinctly different.

Cathode ray tubes can be calibrated to account for changes in luminance caused by pixel adjacency, varying phosphor intensities and beam distortion (Catmull 1979). A gamma correction is incorporated into some high resolution CRTs. The gamma correction accounts for nonlinear changes in luminance due to voltage differences on a CRT, giving a more precise, discernable color gamut. The gamma correction redefines the RGB color system to account for physical color differences based on the luminance of the color. This correction can easily be performed with a photospectrometer. RGB color coordinates are redefined based on the RGB value where significant changes occur in luminance from a fully saturated color to an unsaturated color. The minimum and maximum RGB values where luminosity changes are determined by colorimetric measurement. These values are defined as minimums and maximums for a lookup table, which allows the transformation of values over a specified range. Luminance values can then be determined for specific RGB values, and an equation is determined which will linearize the relationship (Catmull 1979; Watson, et al. 1986).

In computer cartography, color is usually specified in the RGB system. Other color systems have been incorporated on CRTs in order to define color in a perceptual manner. The HLS color system defines color in hue, lightness and saturation. This method attempts to approximate a Munsell color system, but is a linear mathematical transformation of the RGB color system and is not based on perceptual experimentation (Joblove and Greenberg 1978).

Modern computers and standard high resolution CRTs can create more than sixteen million (256^3) colors, for more color possibilities than can be displayed on a screen at one time. A mathematical relationship between physical color systems and perceptual responses is needed for judicious selection of a subset of RGB colors for map categories. One possibility are tints, which can be easily incorporated on CRTs using the RGB color system. Tints are hues which change both in value and chroma, and can range from a white to a dark hue. Tint was initially defined as the colorful component in the Ostwald color system. This is similar to saturation, where there are progressions from light to dark hues. On a CRT, tint involves changes in luminance inherent to the phosphorus guns that create the color. Varying the amount of luminance in two of the phosphorus guns while holding the third constant can create a tint progression which is easily programmable and is an effective way of representing a magnitude progression within a hue.

Computer engineers have recently been concerned with the ergonometric design of CRTs. The appropriate perceptual processing of color has been researched on CRTs, with algorithms developed for the implementation of color ordering systems. Color scientists and computer engineers have commented on the increasing use of color and uniform color systems in automation (Hunt 1985). The differences in color between the CRT and the output device have also been researched. Catmull (1979) noted the nonlinearity between CRT color and photographic film copies of screen images. The use of compensation tables can rectify this problem. This is a significant problem for the computer cartographer who uses the CRT screen as an editing board where design map criteria are established.

McManus and Mead (1984) examined the correspondence of video and hardcopy color. They note that color on video display units (VDU) is usually formed in the RGB system, whereas hardcopy color is formed by the combination of subtractive primary colors (cyan, magenta and yellow). The hardware link between these two systems is complex and usually results in a different color on the hardcopy. VDU color is controlled by three simultaneous voltage intensities and hardcopy color is defined by the fractional area covered by primary inks. McManus and Hoffman (1985) have noted the difference between VDU white (R=G=B=255) and hardcopy white. The VDU white appears distinctively different, with a bluish hue. This is related to color constancy and could introduce error into a psychophysical experiment.

Computers usually rely on the RGB color specification system. Only a few mathematical transformations exist for renoting RGB color space to perceptual color space. The incorporation of uniform color space in computer graphics has been slow due to color's complex properties. Tajima states:

> Because of the cylindrical properties, it is very complicated to compute a color difference between two given colors ... therefore, the Munsell System does not suit high-speed computer graphics (Tajima 1983, p. 306).

Summary

In colorimetry many color specification systems exist. The CIE system is based on luminance and tristimulus variables. The Munsell system is a perceptual system.

Several psychophysical testing methods have been proposed for the examination of color. Two psychophysical methods used in color research are direct estimation and multidimensional scaling. Direct estimation consists primarily of magnitude estimation, partitioning and bisectioning. Magnitude estimation assigns non-anchored values to a stimulus. Partitioning denotes that a series of stimuli is divided into equal classes. Bisectioning consist of dividing stimuli into classes by defining the midpoint in a progression between two defined endpoints. Multidimensional scaling assigns perceptual similarities or dissimilarities between pairs of physical variables.

Psychophysical research in color science has also indicated that graytones are more difficult to categorize in the dark values. A cube root function (Glasser et al. 1958), power function (Godlove 1933; Munsell, Sloan, and Godlove 1933), and sixth-order polynomial (Newhall 1940) have been advocated for adjusting values for perceptual classification of reflected graytones.

Chromatic color has been examined by Planek and Stevens (1966) and Indow and Stevens (1966). These psychophysical studies indicated that power functions best describe how chromatic color is also processed. Fully saturated colors are more difficult to categorize. Lozano (1983) also indicated that chromatic and achromatic color processing may be similar.

Cartographic psychophysical research has examined the mathematical relationship of value, one of the perceptual dimensions of color, with equal contrast scales (Kimerling 1975; Williamson 1982). Value is achromatic and, thus, is perceptually processed in a different manner than chromatic color. Cartographic psychophysical value research has indicated that dark graytones are more difficult to categorize perceptually than light values. This is in agreement with psychological studies and color science research (Stevens 1975; Wyszecki and Stiles 1982).

Olson (1983) has commented on the future of cartographic design research and, the associated psychophysical testing of stimulus response as a major area of future research in computer cartography. With the development of scientifically determined quantitative relationships, the computer can be used effectively to design appropriate visual representations of a spatial distribution. Olson states that with respect to cartographic psychophysical testing:

> Probably the most common uses were in computer mapping, and computers, in fact, will probably be responsible to a large extent both for the continuing interest in the methods and questions of psychophysical studies...(Olson 1983, p. 278).

The establishment of a perceptually uniform color space is a complex problem. The construction of a precise equidistant color space is not of prime concern. More important is formulation of general guidelines that can assist the designer. Newhall, Nickerson and Judd (1943) summarized a valid point in the conclusion to their evaluation for the revision of the Munsell uniform color space.

The problem now seems more complicated than at first; and it may be that greater compromises with the ideal of perceptual uniformity may have been made in order to secure a workable system than was anticipated (Newhall, Nickerson and Judd 1943, p. 418).

CHAPTER 3. METHODS

This research addresses equal contrast tint progressions on high resolution CRTs and is based on a pyschophysical experiment through which the mathematical relationship between computer color and physically based color systems can be determined.

A psychophysical bisectioning experiment was performed to determine equal steps within tint progressions on a high resolution color CRT. Tint was examined because progressions from white to full strength color were sought, similar to printed screen tints for different ink colors. Equal steps for the primary colors of red, blue and green were measured in physical color units (i.e., RGB and 1931 CIE).

Bisectioning creates an equal contrast color scale, which forms the basis for specification of visually equidistant tints on classed choroplethic and dasymetric maps. Bisectioning is similar to partitioning but allows for more control in the presentation of the stimulus, thus eliminating the influence of external factors such as perceptual illusions. Perceptual phenomena, such as mach banding, will profoundly impact the results. Only one perceptual task is required in a bisectioning experiment. Bisectioning is carried out one step at a time with other steps not in view and the step being created not always in close proximity to the previous darker and lighter stimulus colors. In a partitioning experiment all stimuli are presented at once and the subject can interactively change the stimuli which define the progression.

Twenty test subjects were tested for color deficiency using the Ishihara (1954) color blindness test. Two color deficients (deuteronopes) were used in the test. Color deficients serve as good controls because they mix only one or two colors. The mixing of only two colors reduces the three dimensionality of color and simplifies the color space. The ages of the subjects ranged from 19 to 32. Both females and males were tested and test subjects had various educational backgrounds.

The color stimuli were presented on a Hitachi high resolution graphic CRT controlled by a Raster Technologies Model One/25 display driver on a Gould SEL 32/67 minicomputer. The stimuli were presented in a vertical manner to control for right brain / left brain interaction. Psychological research has indicated that neurological processing is different in the right and left hemispheres of our brains. A vertical stimulus allows similar fixations with no predominance between the eyes, thus controlling hemispherical interaction. A neutral gray background was used as a control to minimize the influence of simultaneous contrast and CRT calibration. The CRT is calibrated so that colorimetric coordinates vary depending on the background. Specific colorimetric coordinates are different on a black or a white background. A gray background can minimize the colorimetric changes due to automatic gain on the CRT. On a CRT the background surrounding a color will profoundly impact the excitement of the phosphor on the screen. As more electrons are active on the screen, their influence on a colored area may change.

The test subjects were presented with instructions that described four alternatives for changing the color on the CRT. Four cursor keys were programmed to change the color in various amounts: darken or lighten a lot (a decrease/ increase of 5 RGB values) and darken or lighten a little (a decrease/ increase of 1 RGB value). The subjects had no time limit and could adjust the color any number of times (Appendix B contains experiment and data collection programs).

Colorimetric measurements were made on the RGB values defined by the test subjects. After the completion of the perceptual test, CIE color coordinates were measured with a Minolta Chromameter Model CL-100 for each color selected by using tristimulus color filters, and CIE illuminant A as the calibration standard. This reference is the standard for daylight conditions. The experiment, however, was performed in more standard CRT viewing conditions with back illumination from flourescent lights. This created a constant shift in the CIE color space definitions of the colors.

In the bisectioning experiment, each subject partitioned a tint scale by interactively defining colors that were at the perceptual midpoint between two previously defined colors. Twenty test subjects repeated the experiment twice on hues of red, blue and green. Figure 5 shows the manner in which the colors were bisected. Initial endpoints of white and a fully saturated color were presented and the test subject defined the perceptual midpoint by pressing options programmed on the cursor pad for increasing or decreasing the center color. This midpoint was used for the subsequent bisection. Each test subject performed seven bisections, thereby creating a nine - step progression, with only one bisection being presented at a time. All bisections were dependent upon previous bisections within a hue.

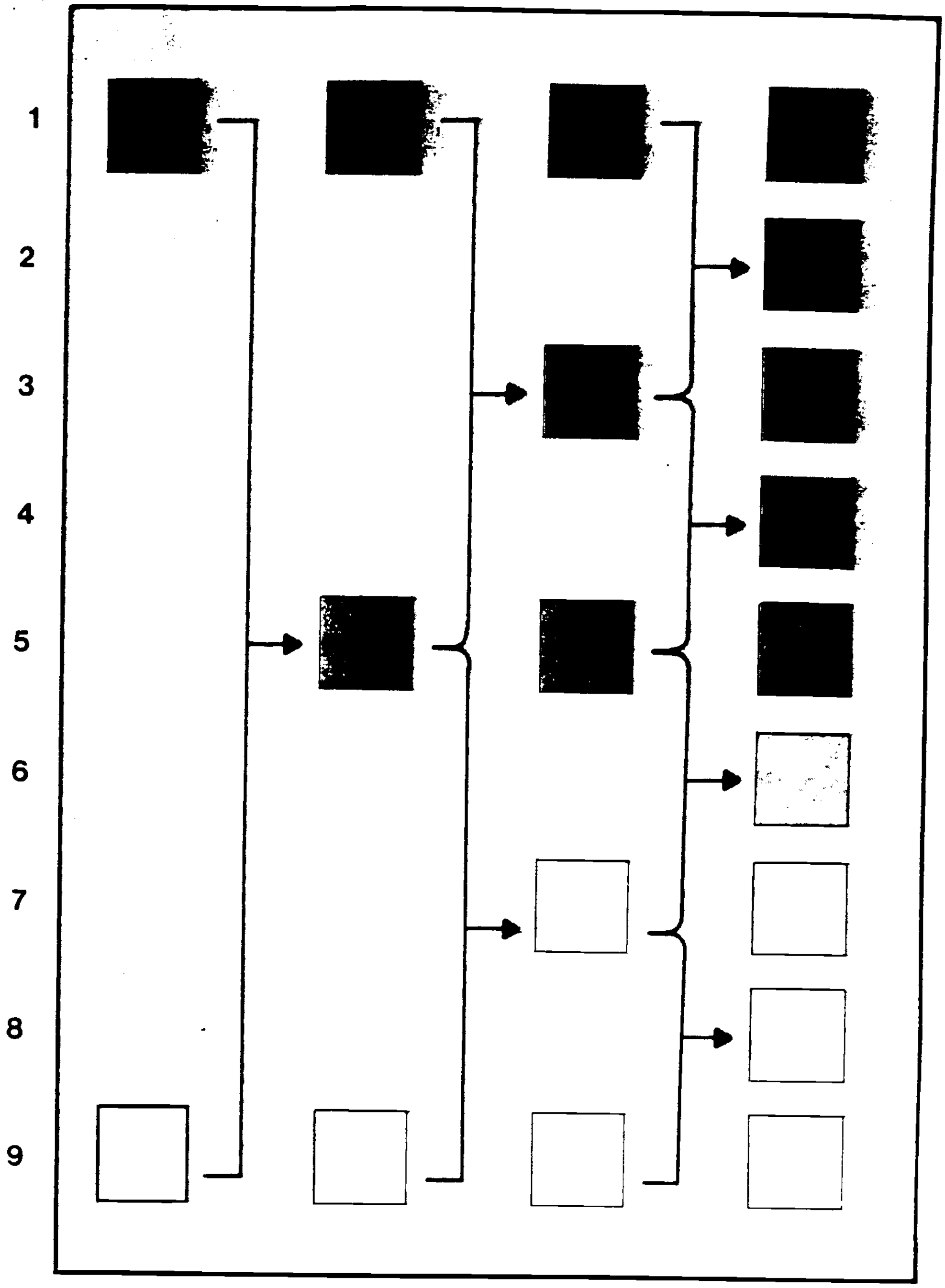


Figure 5. Bisectioning sequence for tints on a CRT. Pairs of tints where presented, which in turn became endpoints for subsequent bisections. One pair was presented for each bisection.

Test subjects were not informed that they were perceptually defining nine tints between white and a fully saturated hue. Viewing angle, viewing distance, and lighting also were controlled to reduce experimental error caused by glare and other extraneous factors. The viewing angle was over 80 degrees, sufficiently large for a retinal image. Slight variations occurred due to height differences among test subjects. The test subject's head was approximately one meter from the CRT. The room illumination was overhead flourescent lights two meters above and one meter behind the CRT. This back illumination reduced glare on the CRT screen. Hysteresis, the difference due to stimulus presentation order, was minimized in the experimental design by having the test subjects define the colors once from a white and once from a fully saturated background.

To reduce simultaneous contrast, brightness constancy, and mach banding, the experiment was performed with non-cartographic examples (large squares). These perceptual phenomena may induce larger variations in the perceptual responses.

Data Manipulation and Analysis

The RGB values, defined in the bisectioning experiment, were stored in a sequential data file on the computer. These RGB values were subsequently used for the determination of the CIE values. A FORTRAN program (Appendix B) was used to replicate the experiment and allow colorimetric measurments with the chromameter.

The sequential data file on the Gould minicomputer was transferred to an IBM microcomputer where graphical analysis was performed with Lotus 1-2-3. A data file was also transferred to Oregon State University's Control Data Corporation (CDC) 720-140 mainframe computer. Data from this file were analyzed with the Statistical Package for the Social Sciences (SPSSx). The statistical analysis consisted primarily of two techniques: gamma correction and color dimensionality reduction. Nonlinear regression was used to derive a gamma correction function which identifies the nonlinear relationhips between computer specified color and physical based color.

Principal component analysis reduces the multidimensional properties of tint.

CHAPTER 4. RESULTS

The luminance and (x,y) tristimulus values of the CIE color space were defined in the bisectioning experiment based on the perceptual responses of test subjects. The perceptual responses represented on a standard CIE chromaticity diagram (Figure 6) reveal the tint progression in the color space. Three radiating curves are presented in the diagram. The center loci is the tristimulus definition of white on the CRT. The periphery of the diagram indicates wavelengths of monochromatic color. The radiating curves represent progressions from the corresponding dominant wavelengths of red (700 nm), green (546 nm) and blue (435 mn).

The third dimension of the CIE color diagram is the luminance (Y). Luminance variation on the CRT can be corrected with the gamma correction factor. The uncorrected Hitachi CRT can be corrected based on CRT luminance of the red, green and blue channels defined by the test subjects. Figure 7 represents blue RGB values, plotted on the vertical axis, related to the CIE Y

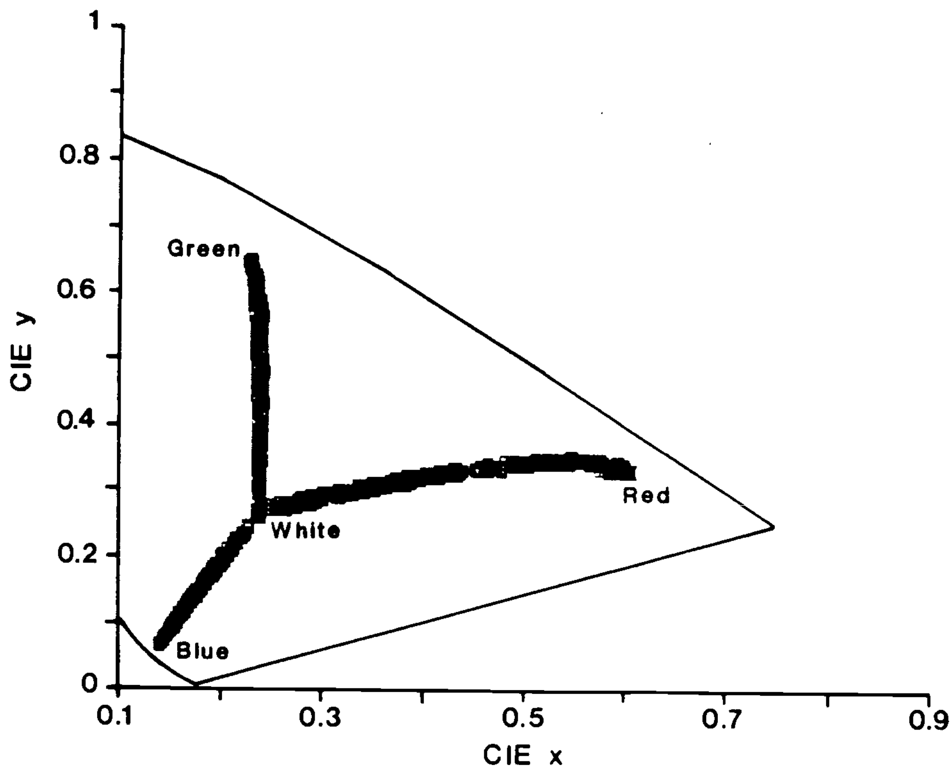


Figure 6. Chromaticity diagram. Individual squares are perceptual responses for tint from white to red, green and blue. Tint progressions appear to be nonlinear functions of the tristimulus variables.

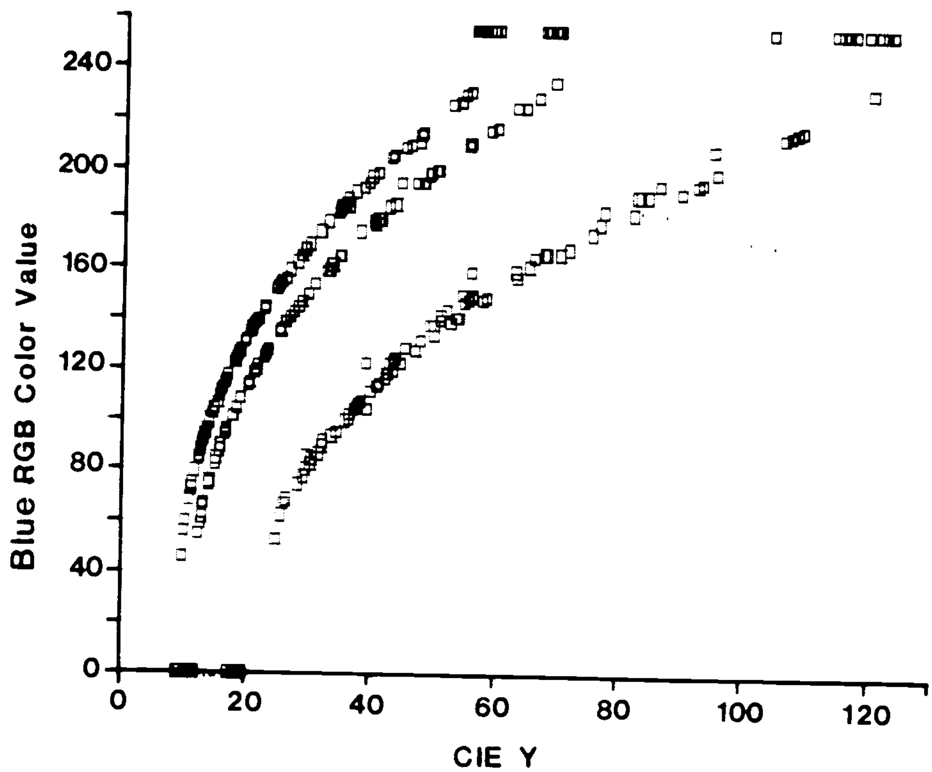


Figure 7. Blue RGB values related to luminance values indicating a nonlinear relationship between blue RGB color values and the luminosity of a tint. This can be reduced with the gamma type correction. Squares represent individual perceptual responses.

(luminance value) represented on the horizontal axis. Luminosity increases dramatically in the fully saturated colors. Three distinct curves are present and are most likely due to slight changes in the calibration of the CRT over time. The contrast and brightness settings on the CRT profoundly impact the luminosity of the defined color. In this experiment the contrast and brightness were not changed and variation can be attributed to use of the CRT over a long time span. Similar results were found for red and green (Figures 8 and 9). The data for the green were less clustered along the line because of the high reflective properties of green on this CRT, but the relationship between RGB values and luminance were very significant (p value=0.0001) when a logarithmic transformation was applied. RGB values are nonlinearly related to luminance but can be corrected with the gamma correction. Logarithmic transformation of individual guns can be combined into a power function for all three guns (achromatic tints).

The RGB values were next plotted against the tristimulus values (x,y). The red RGB values plotted against the x tristimulus value revealed logistic relationships (Figure 10). A dramatic shift was apparent

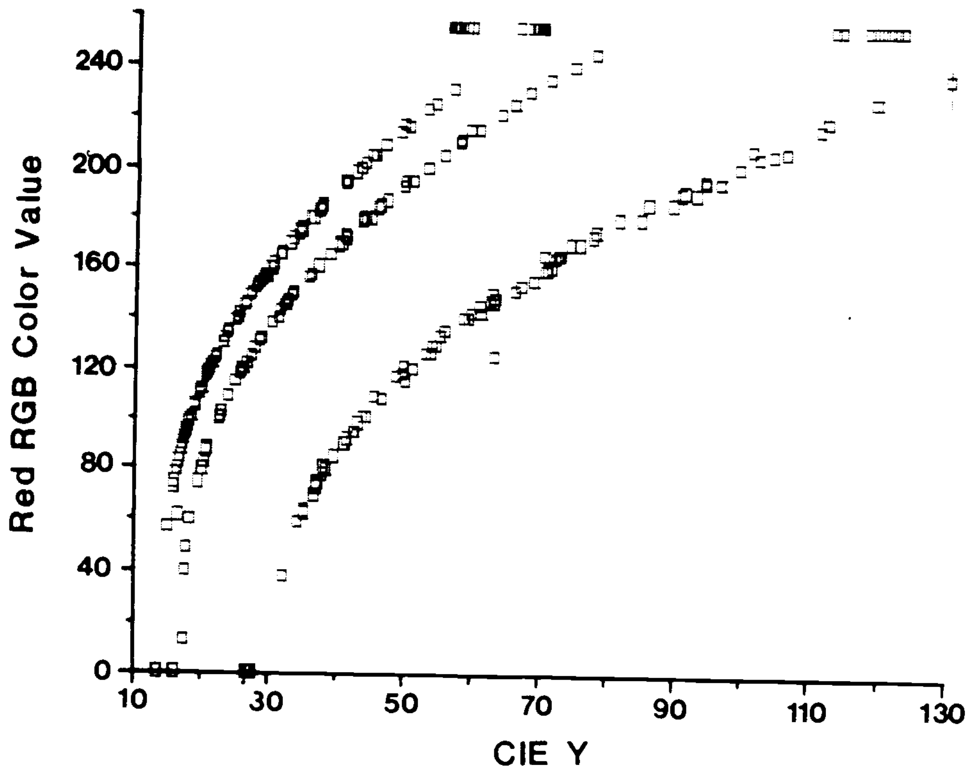


Figure 8. Red RGB values related to luminance values indicate a nonlinear relationship between computer specified color and luminosity of a tint. This can be reduced with a gamma type correction. Squares represent individual perceptual responses.

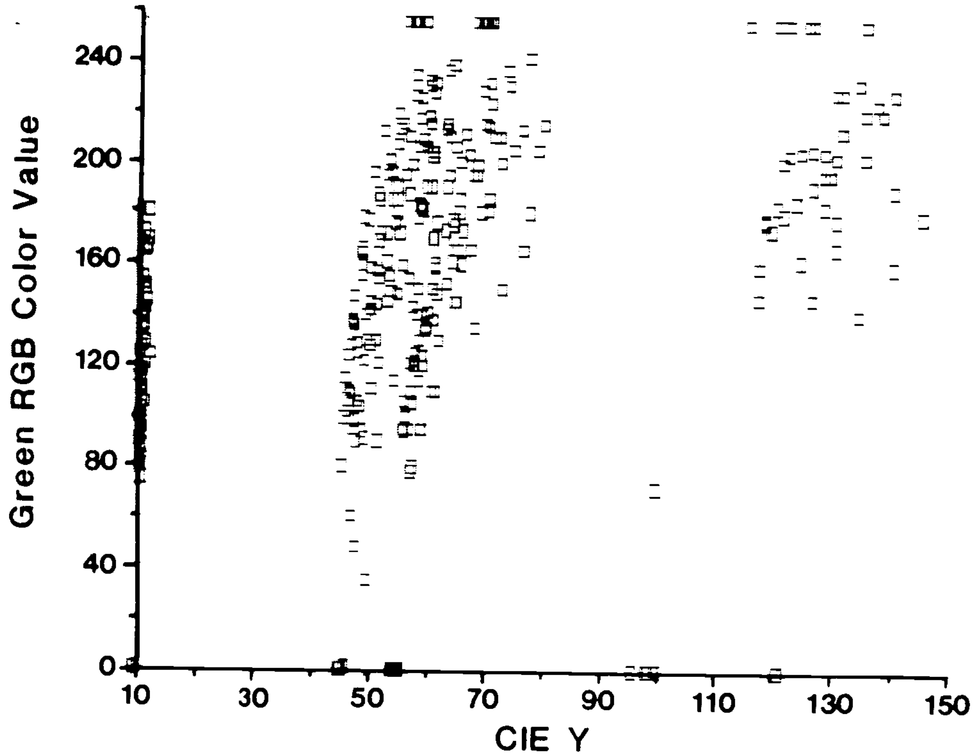


Figure 9. Green RGB values related to luminance values indicate a nonlinear relationship between computer specified color and luminosity of a tint. This can be reduced with a gamma type correction. Squares represent individual perceptual responses.

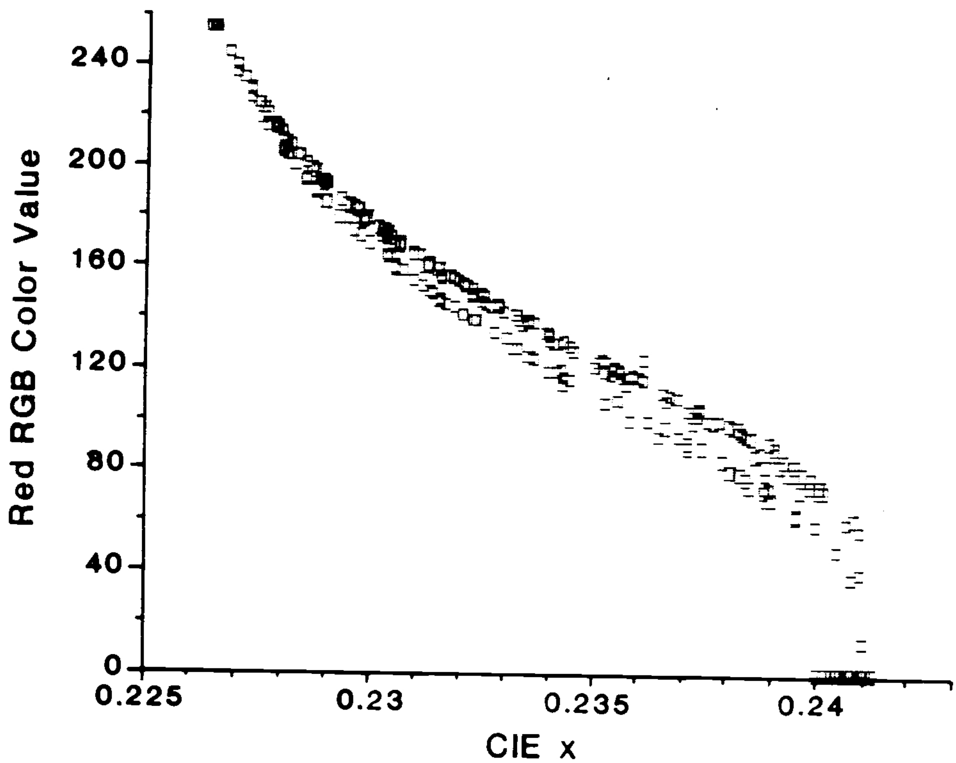


Figure 10. Red RGB values related to tristimulus x indicate a nonlinear relationship between computer specified color and the CIE x values for a tint. Squares represent individual perceptual responses.

in the dark end of the tint progression. The y tristimulus variable had a similar pattern (Figure 11). This pattern was not as pronounced because y remained fairly constant throughout the red progression (Figure 7) These nonlinear relationships of RGB values to the chromaticity coordinates indicate the relationship between the CIE color space and the RGB color specification on the CRT.

The blue values, when plotted against chromaticity, indicated an inverse exponential relationship (Figures 12 and 13). Again, the nonlinearity between the RGB values and the chromaticities was in the fully saturated tints.

The green RGB values showed an inverse exponential relationship to the y tristimulus variable (Figure 14). The x tristimulus variable did not have a strong relationship with green RGB values (Figure 15) because this variable does not change significantly in a progression from white to fully saturated green (Figure 7).

Munsell Renotations

The perceptual responses, represented on a chromaticity diagram with the Nickerson Munsell renotation

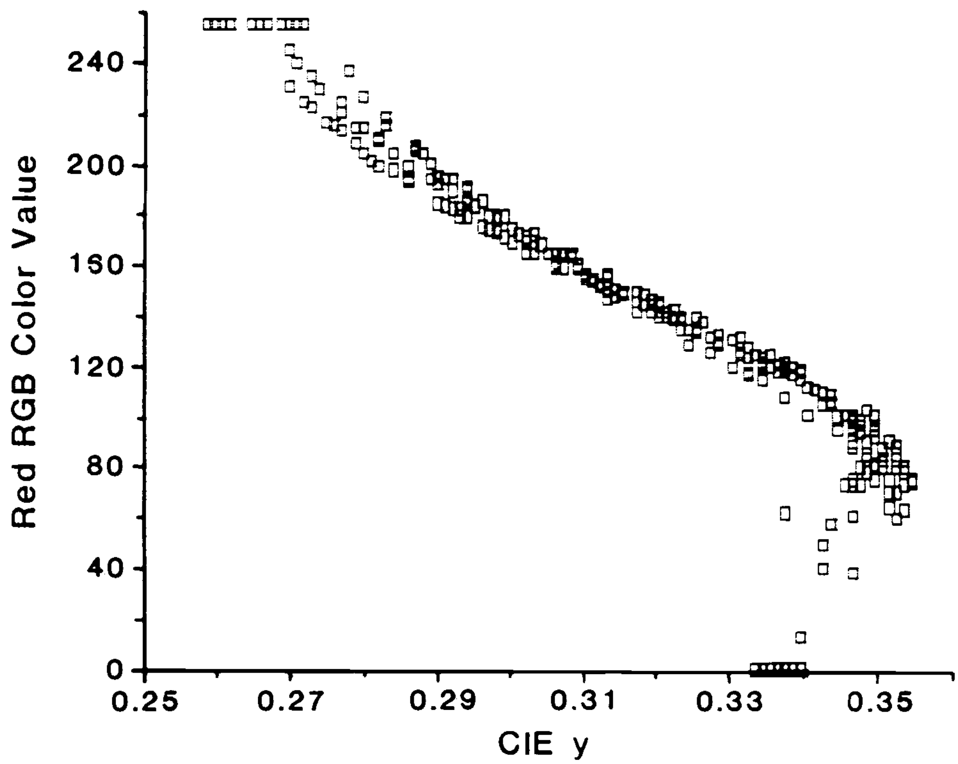


Figure 11. Red RGB values related to tristimulus y indicate a nonlinear relationship between computer specified color and the CIE y values for a tint. Squares represent individual perceptual responses.

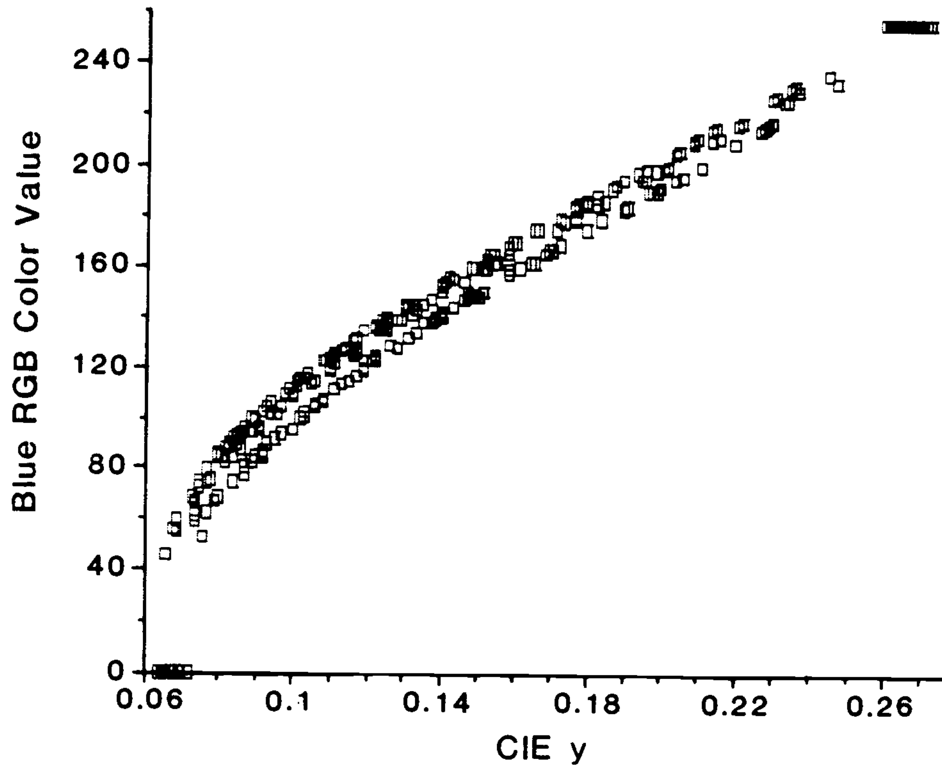


Figure 12. Blue RGB values related to tristimulus y indicate a nonlinear relationship between computer specified color and the CIE y values for a tint. Squares represent individual perceptual responses.

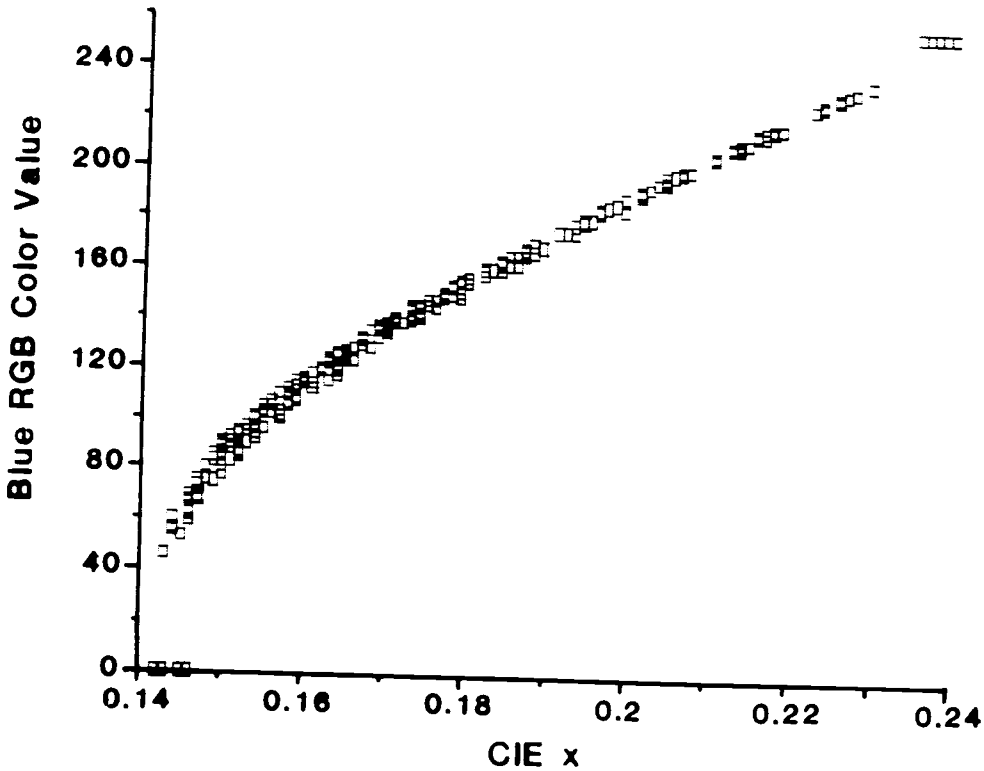


Figure 13. Blue RGB values related to tristimulus x indicate a nonlinear relationship between computer specified color and the CIE x values for a tint. Squares represent individual perceptual responses.

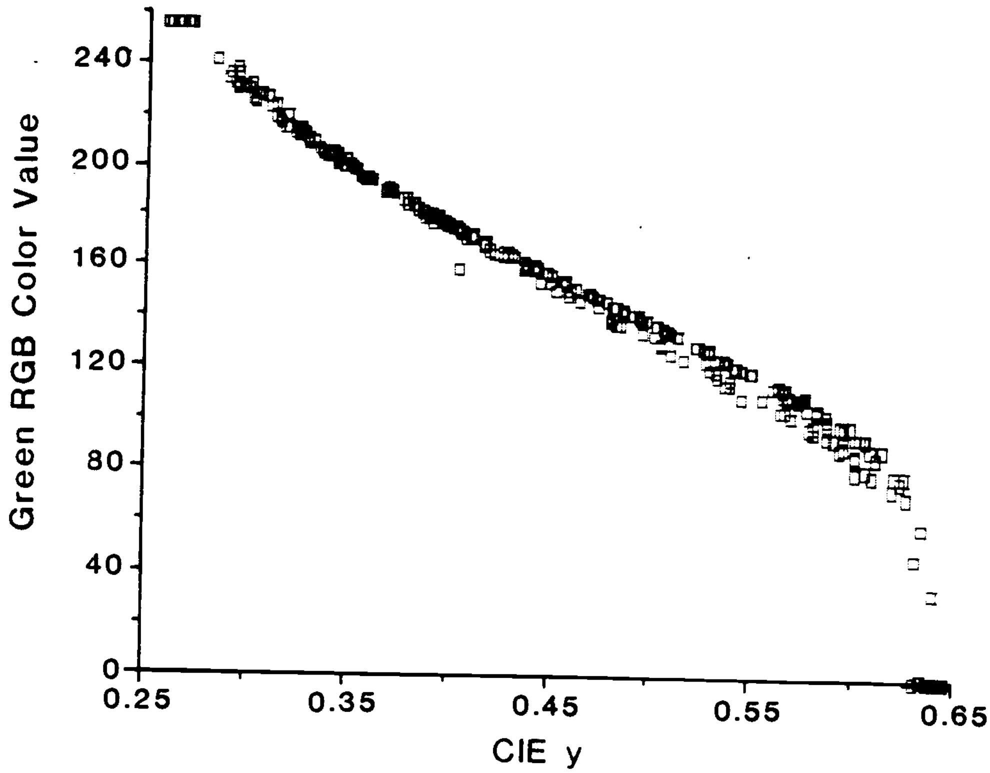


Figure 14. Green RGB values related to tristimulus y indicate a nonlinear relationship between computer specified color and the CIE y values for a tint. Squares represent individual perceptual response.

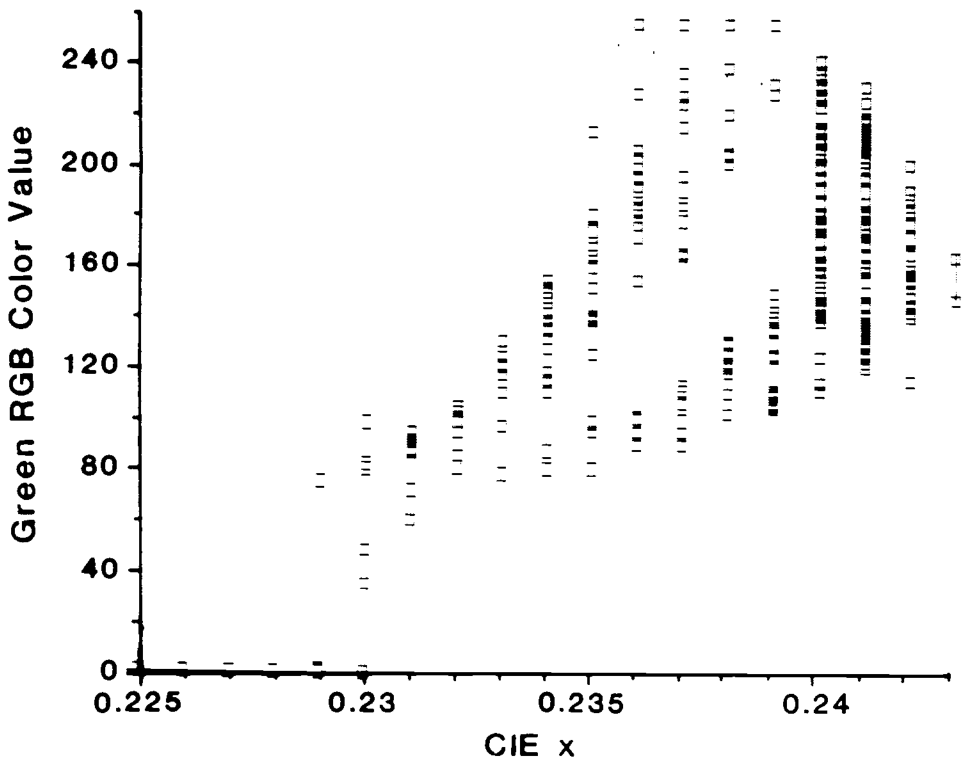


Figure 15. Green RGB values related to tristimulus x indicate a nonlinear relationship between computer specified color and the CIE x values for a tint. Squares represent individual perceptual response.

for constant values (9 representing light values and 1 dark values), are presented in Figure 16. Tint, for red and blue, appears similar to chroma but is different for the constant Munsell values. The tint progressions do not follow a chroma progression but, rather, appear to be a function of both Munsell chroma and value. The green tint progression, from the bisectioning experiment, is drastically different from the Munsell renotation and appears similar to a yellow-green chroma progression. The differences between the tint and chroma progressions are due to fluctuations in saturation. Tint has characteristics similar to saturation, such as non-constant luminance, whereas chroma has constant luminace.

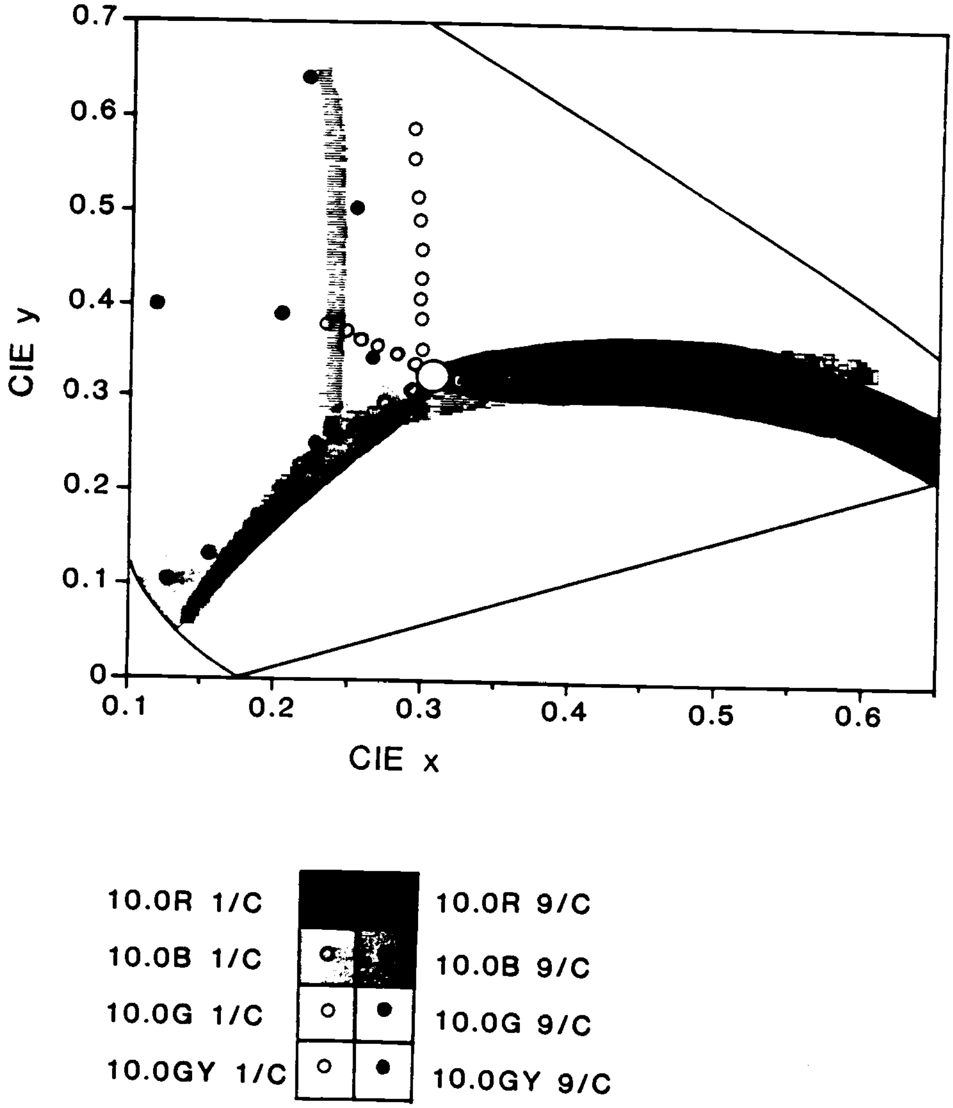


Figure 16. Chromaticity diagram with Nickerson Munsell renotation for constant values of 1 and 9. Gray squares represent individual perceptual responses.

Gamma Correction

A gamma-type correction was determined for the red, green and blue CRT guns. Logarithmic transformation of the luminance produced higher linear correlations (Pearson's r > 0.96) for the individual guns. Variations in the coefficients are due to changes in the phosphorus gun calibrations. A typical gamma correction of achromatic values yields a power function. This corresponds mathematically to indiviual logarithmic transformations for the three RGB guns. The transformation for an individual gun should maintain luminance across RGB values for an individual tint progression. Interaction terms were incorporated into the RGB tint models to remove calibration errors and to test for differences in the slopes and intercepts of the defined equations. The interaction terms for changes in the slopes of the equations were not statistically significant at the 0.10 alpha level. The interaction terms for parallelism were statistically significant at the 0.0001 alpha level. This indicates that the calibration error changes the intercept but the slope of the equation is constant. Thus, changes in brightness and contrast affect the base for the curve but not the underlying relationship. Table 6 presents the models for the gamma type corrections for the red, green and blue guns.

The predicted gamma-corrected values from the regressions were examined for the nine perceptual categories. The relationship was approximately linear, indicating that linear tint progressions on gamma corrected terminals may be perceptually linear. This is not the case, however, because RGB values are not a physical measure of color and can not be used to determine a psychophysical function.

Color Dimensionality Reduction

A three-dimensional diagram of the 1931 CIE color space reveals the multidimensional properties of tint. A tint progression is a function of both the luminance and the tristimulus variables, and is a nonlinear relationship (Figure 17). Multivariate statistics allow the dimensionality of tint to be reduced to one physically based variable (Dillion and Goldstein 1985).

The nonlinearities in the color space were removed by log-log transformations. Transforming the data into linear equations allows the variables to be reduced to one variable through principal component analysis (PCA). Table 7 presents the eigenvectors and eigenvalues of the

Table 6. Gamma Correction Models for red, green and blue. Interaction terms indicate variable intercepts but constant slopes within colors. Intercepts, slopes and adjusted R^2 are presented.

	Model	Intercept	Slope (ln)	Adjusted R^2
Red	1	-412.7	166.1	0.99
	2	-447.7	166.1	
	3	-549.5	166.1	
Green	1	-1412.4	627.3	0.83
	2	-2344.7	627.3	
	3	-2463.4	627.3	
	4	-2829.3	627.3	
Blue	1	-292.1	135.4	0.99
	2	-318.9	135.4	
	3	-403.0	135.4	

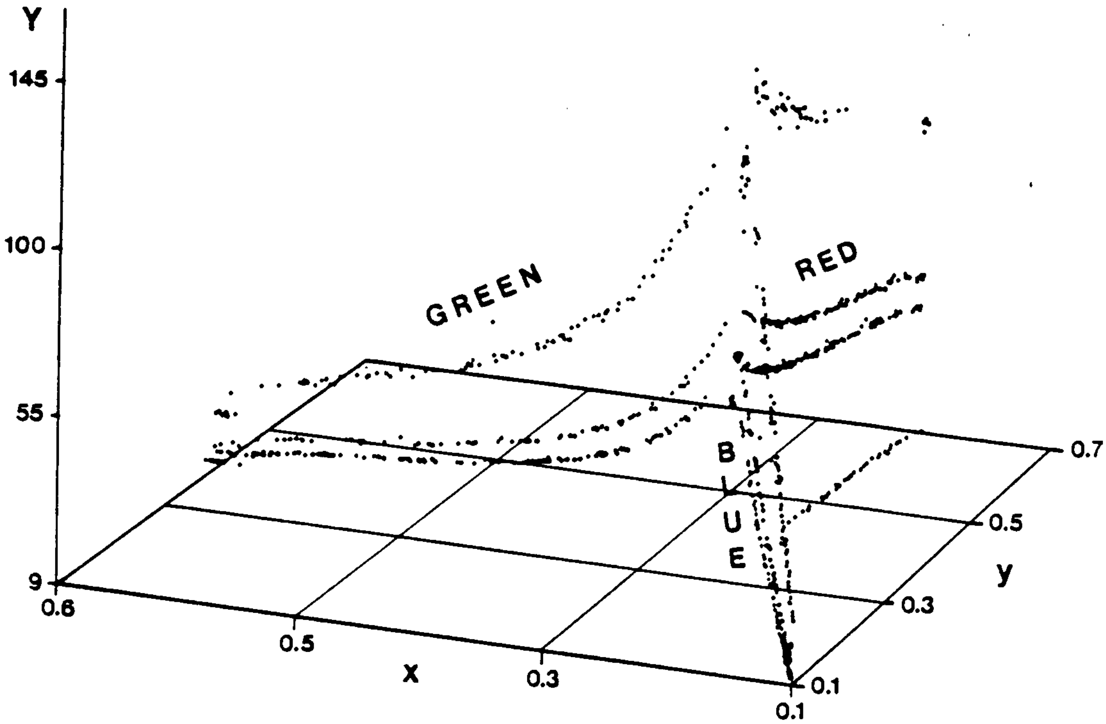


Figure 17. Tint progression in three dimensional CIE color space. This diagram reveals the multidimensional properties of tint progressions as a function of the tristimulus variables and luminance. Dots represent individual perceptual responses.

Table 7. Eigenvector and Eigenvalues for red, green and blue tint variables.

Color	Eigenvector	Eigenvalue	Pct of Variation
Red	$(Y^{-0.89})(x^{0.98})(y^{0.95})$	2.67	88.9
Green	$(Y^{0.73})(x^{0.81})(y^{-0.86})$	1.93	64.4
Blue	$(Y^{0.94})(x^{0.99})(y^{0.99})$	2.81	93.7

equations. The first component, corresponding to tint, accounts for 89, 64 and 94 percent of the variation for red, green and blue progressions. The eigenvectors show the influence of the CIE variable in the equation.

The eigenvector was transformed by a log - log transformation, thus creating a power function for the individual variables. The first component, tint, is a power function of the CIE chromaticity coordinate and luminance. The coefficients are slightly less than one, indicating that slight changes in the dark tints are larger than slight changes in the lighter tints. This factor is accentuated by multiplying the terms in the eigenvector by one another.

To determine the psychophysical relationship, the perceptual categories were plotted against the multidimensional variable for the CIE color system. The tint variable, as defined by the nonlinear power transformation of the CIE color space, shows a slight power function when plotted against the perceptual categories. These curves indicate that tint categorization is more difficult in the dark tints. The means of the perceptual bisections with 95 percent confidence intervals are plotted in Figure 18. A slight nonlinear relationship can be noted. The physical

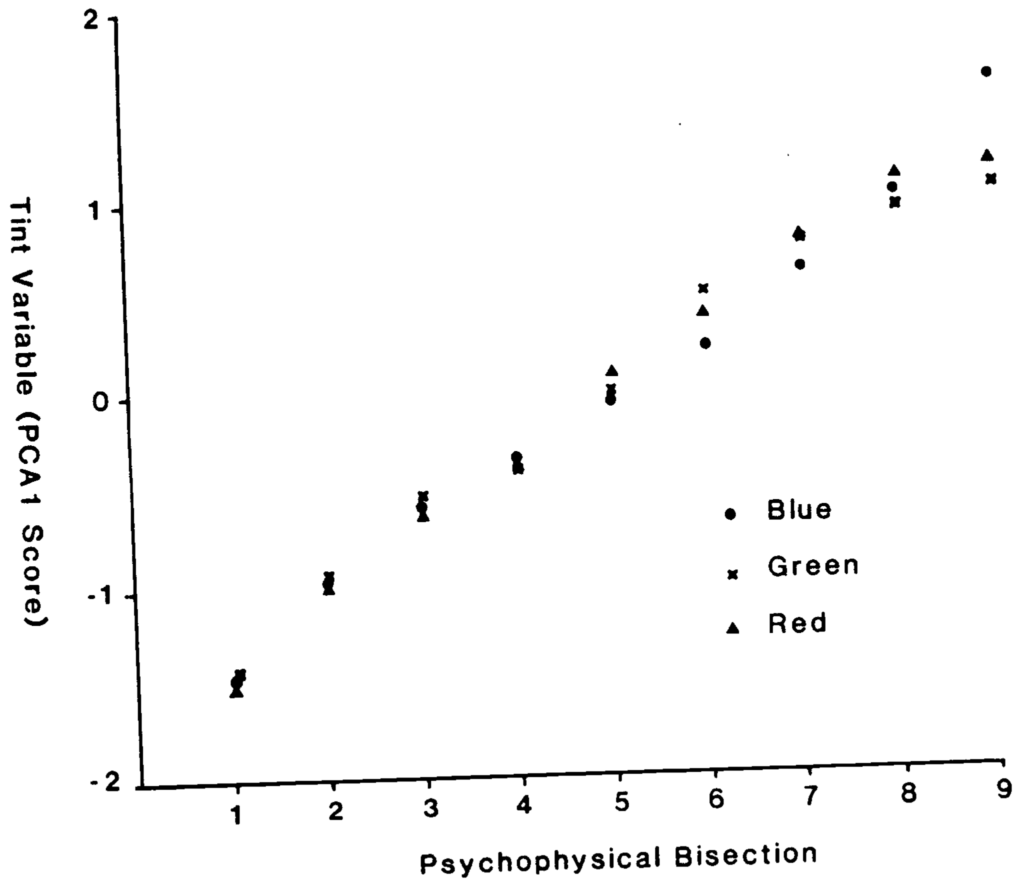


Figure 18. Plots of tint means by psychophysical bisection. Note the a slight nonlinear function.

variable tint, though, is a nonlinear power function of the colorimetric measurements.

The perceptual responses also affect the dimensionality of color. The relationship between the derived tint variable and the RGB values reveals a slight exponential relationship (Figures 19, 20 and 21). The nonlinear transformations from the principal component analysis do not have linear relationships with the RGB values. The derived power function explained the majority of the variations (as seen in an examination of the eigenvalues) and assisted in the linearization of the variable. The nonlinearities in the color space for the tint progressions can be directly attributed to the CRT color specification. An examination of tint and RGB values reveals that the fully saturated tints have greater increases in the RGB values. This causes the psychophysical function to be exponential in nature, indicating RGB value changes in the saturated colors are more difficult to perceptually categorize.

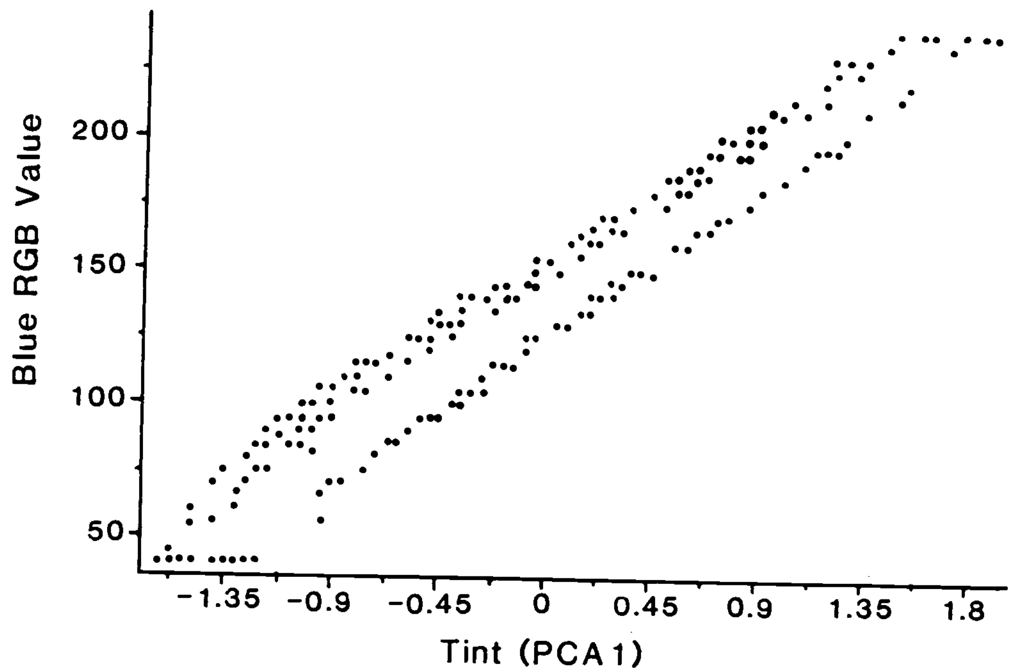


Figure 19. Blue RGB values plotted with the corresponding tint variable derived from the principal component analysis. An exponential relationship reveals that fully saturated tints are nonlinear with respect to RGB.

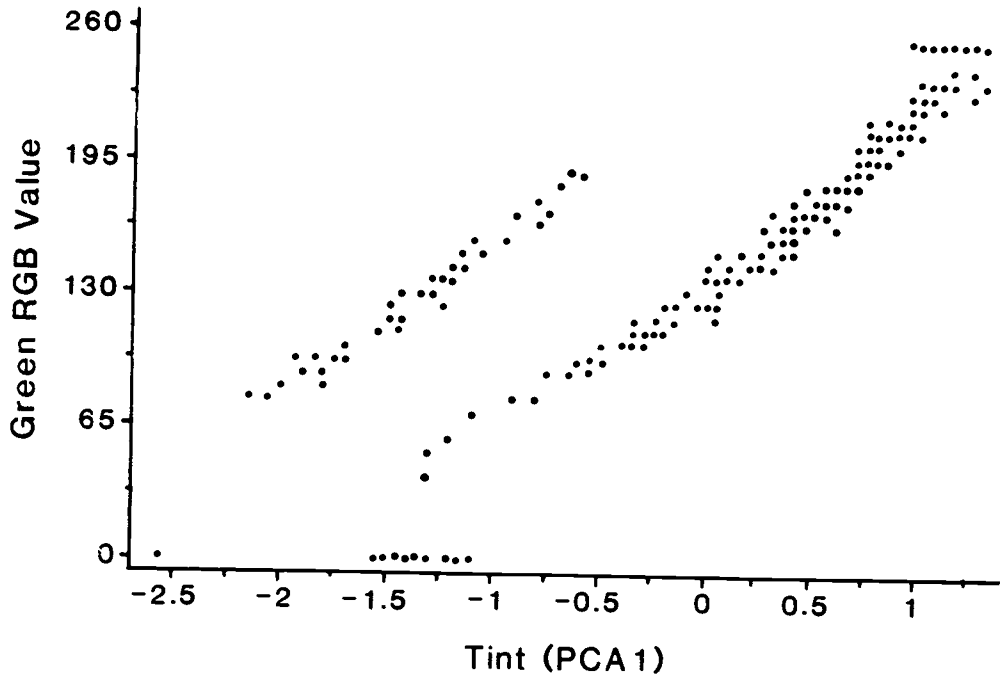


Figure 20. Green RGB values plotted with the corresponding tint variable derived from the principal component analysis. An exponential relationship reveals that fully saturated tints are nonlinear with respect to RGB.

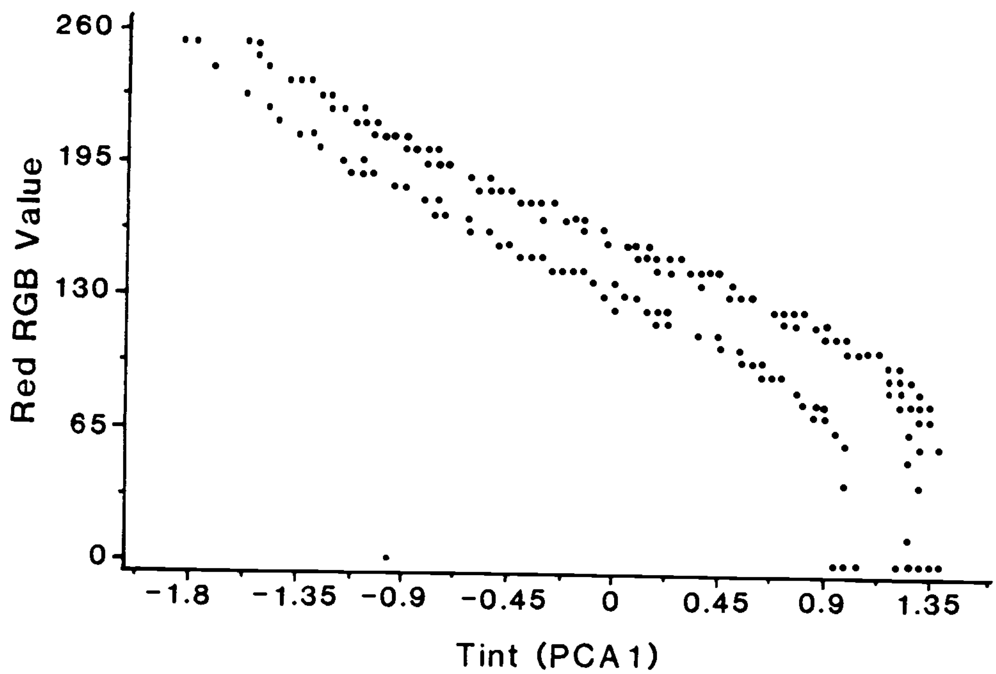


Figure 21. Red RGB values plotted with the corresponding tint variable derived from the principal component analysis. An exponential relationship reveals that fully saturated tints are nonlinear with respect to RGB.

Time to Perform Bisections

The time to perform a bisection was measured to determine if any color adaptation was occurring. No patterns were apparent related to time, the RGB value, or the bisection. Figures 22, 23 and 24 reveal no trends in the time required to defined RGB values for the seven bisections. Time does not appear to influence the bisections for the RGB values.

Color Deficients

The color deficients did not differ from the color normals in their perceptual responses. The deficients were deuteronopes (i.e., two hues mixed to create all colors), and this experiment was performed within single hues for each bisection, thus controlling for color defiencies. Red, green and blue tint progressions may in fact be an effective design strategy for presenting quantitative cartographic information to deuteronopes.

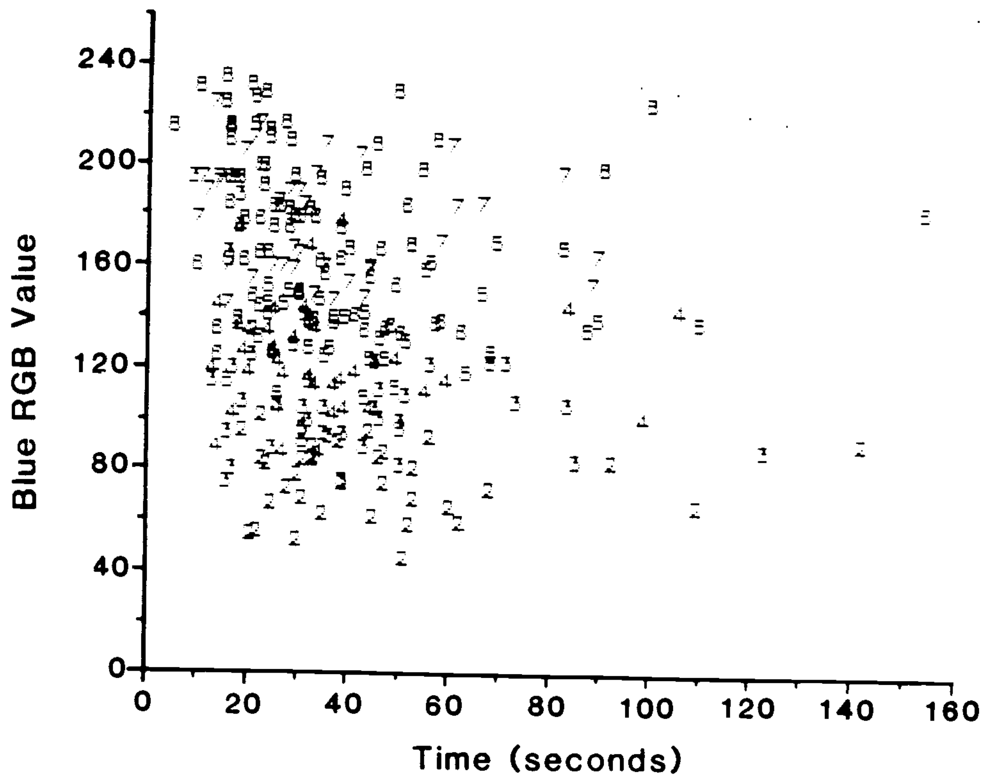


Figure 22. Time to perform bisection plotted by blue RGB value by bisection.

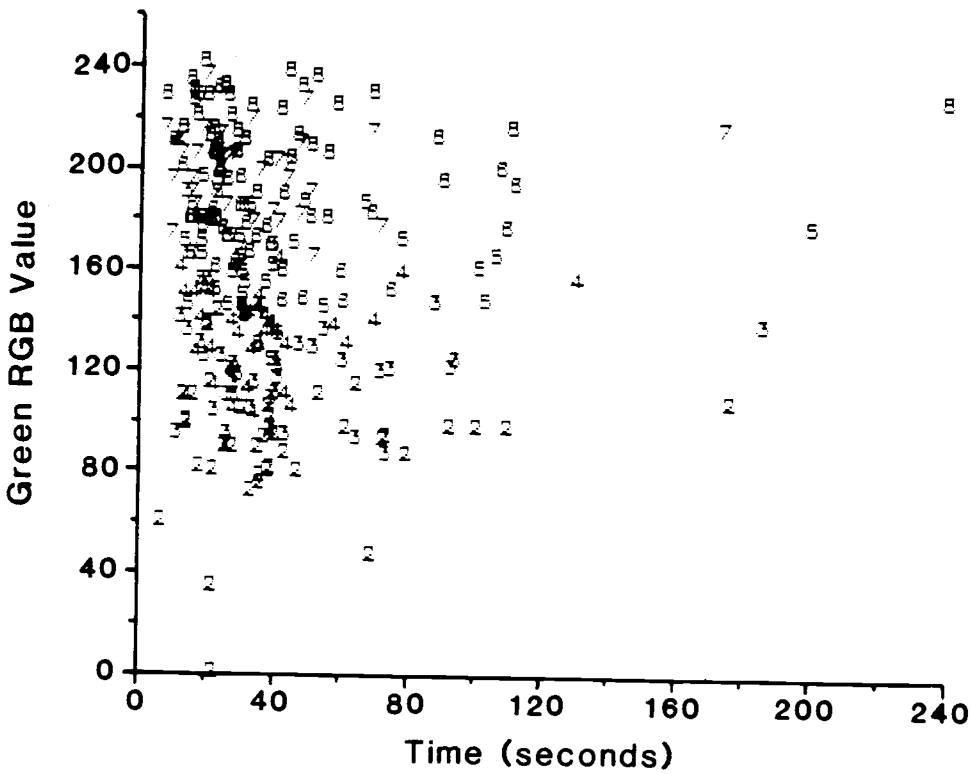


Figure 23. Time to perform bisection plotted by green RGB value by bisection.

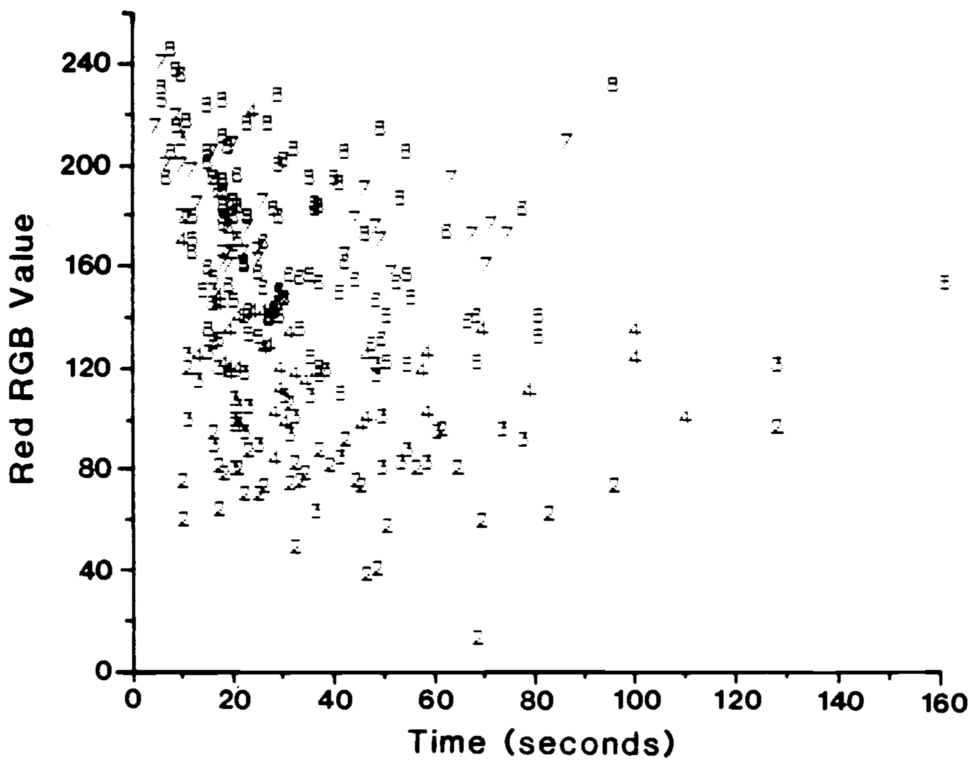


Figure 24. Time to perform bisection plotted by red RGB value by bisection.

CHAPTER 5. DISCUSSION

Overall, the mathematical relationships for defining tint are complex due to the multidimensional properties of color. Tint can be expressed as a mathematical function of the chromaticity coordinates and the luminance of color. Results from this research can assist the computer cartographer in color specification on high resolution CRTs. Dark tints do not appear to be perceptually equidistant relative to light tints. This is apparent, based on the perceptual responses in CIE and RGB color space. The psychophysical experiment indicates that tint progressions in near fully saturated hues should be employed cautiously.

Gamma uncorrected RGB values will be distinctively different between CRTs because no physical reference exists for the color specification. Thus, to standardize CRT color specification, gamma corrections should be performed on CRTs. Logarithmic RGB transformation revealed a near linear relationship when related to perceptual classes, indicating that tint on gamma-type corrected terminals can be linearly stretched to create tint progressions. Color in psychophysical tests must be defined in physical units in order to evaluate the derived functions (Meyers 1982). The nonlinear nature of the derived tint variable accentuates the difficulty of categorizing dark tints as compared to lighter tints. Psychophysical experiments require the use of physically based measurements for the independent variable.

The tint variable derived in this experiment was a nonlinear transformation of the CIE color space (Table 6). This transformation, derived to explain the majority of the variation by principal component analysis, had coefficients which were power functions of the CIE variables. The coefficients in this equation are multiplied by one another to create the tint variable. The coefficients were all less than one, indicating that as luminance and the tristimulus variables increase, tint increases respectively less. This demonstrates that tint is a power function of the CIE color space.

The nonlinear tint variable was used as the physical measure for the psychophysical function. The relationship between the tint variable and the psychophysical bisections must be interpreted cautiously. The psychophysical function (Figure 18) revealed a slight convex shape, especially in the low tint values which represent the fully saturated tints. Two factors will profoundly impact the interpretation of the psychophysical function: one, that tint is a nonlinear function of physical CIE variables due to the CRT calibration; and two, that the perceptual classes are nonlinearly related to tint.

The tint variable was not entirely linearized by the principal component analysis. When dealing with n-dimensional hyperspace, it is difficult to control for nonlinear relationships in all dimensions. Color research is suited well to multivariate statistics because of the hyperdimensional properties of color. Color has three specification dimensions (in CIE color space: Y,x,y) and in this research has a dependent axis of computer specifed color (RGB values).

Recommendations for future research are first that color space verification utilizing multidimensional scaling may provide insights into the nature of a uniform color space. The multidimensional properties of color are well suited to this research methodology. Another way to improve test results is to incorporate gamma corrections before data collection.

The exact nature of the RGB color system is dependent on the CRT used. Other color specification systems can assist the cartographer for the creation of color progressions. CRTs are initially calibrated to the CIE color system but can change due to environmental conditions such as usage patterns, humidity and room location. Verification of colorimetric calibration can be easily performed with a colorimeter. The $L^*u^*v^*$ color system can be mathematically transformed into the Munsell color space, which is suited for cartographic color specification. For example, Munsell color can be used in bivariate mapping within a single hue. The two data sets could be made to correspond to value and/or chroma changes. This mapping technique may be an effective method for presenting two highly correlated sets of data on one map. The Munsell system also contains perceptual properties that maximize the communication of the data from the map to the reader.

Table 8 presents general recommended RGB values, based on this research, for defining equal contrast tint values on a high resolution CRT. These values are perceptually equi-distant tint progression scales and can assist in the design of a classed map. These RGB values are dependent on the methodologies used in this research.

Table 8. Recommended RGB values for equi-distant red, green and blue tint progressions

		RGB Values								
		Red			Green			Blue		
		R	G	B	R	G	B	R	G	B
Saturated	1	255	0	0	0	255	0	0	0	255
	2	255	80	80	90	255	90	80	80	255
	3	255	105	105	120	255	120	105	105	255
	4	255	125	125	140	255	140	125	125	255
	5	255	140	140	160	255	160	140	140	255
	6	255	160	160	180	255	180	160	160	255
	7	255	180	180	200	255	200	180	180	255
	8	255	200	200	220	255	220	200	200	255
White	9	255	255	255	250	255	255	255	255	255

This research has produced results similar to prior research on achromatic and chromatic color, that is, perceptual color progressions are nonlinear in nature. Prior research in psychology and color science has indicated power functions for achromatic and chromatic color progressions. This research revealed a power function transformation of emitted tints and perceptual classes on high resolution CRTs.

NOTES

1. For a cartographic color experiment the reader is directed to Eastman (1986).

2. Marcus, Utter and Wilkinson (1976) have addressed this problem in relation to color research.

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APPENDICES

APPENDIX A: Data

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	1	2	0	0	0	255	11.2	0.142	0.066
1	1	2	0	0	0	255	11.3	0.143	0.065
1	1	2	0	0	0	255	12	0.145	0.07
1	1	1	0	0	0	255	11.5	0.143	0.066
1	1	1	0	0	0	255	11.4	0.143	0.066
1	1	1	0	0	0	255	11.4	0.143	0.066
1	1	2	0	0	0	255	9.7	0.143	0.065
1	1	2	0	0	0	255	9.6	0.142	0.065
1	1	1	0	0	0	255	9.4	0.142	0.064
1	1	2	0	0	0	255	9.4	0.142	0.065
1	1	1	0	0	0	255	9.7	0.143	0.066
1	1	2	0	0	0	255	9.5	0.142	0.064
1	1	2	0	0	0	255	9.5	0.142	0.064
1	1	1	0	0	0	255	19.6	0.142	0.067
1	1	1	0	0	0	255	19.8	0.142	0.067
1	1	2	0	0	0	255	19.5	0.142	0.065
1	1	1	0	0	0	255	19.6	0.142	0.065
1	1	2	0	0	0	255	19.5	0.142	0.065
1	1	1	0	0	0	255	17.7	0.143	0.064
1	1	2	0	0	0	255	19.3	0.143	0.066
1	1	1	0	0	0	255	11.3	0.143	0.065
1	1	1	0	0	0	255	11.2	0.142	0.065
1	1	2	0	0	0	255	12.3	0.146	0.072
1	1	2	0	0	0	255	11.5	0.143	0.067
1	1	2	0	0	0	255	11.4	0.143	0.066
1	1	1	0	0	0	255	9.7	0.143	0.065
1	1	2	0	0	0	255	9.5	0.142	0.064
1	1	2	0	0	0	255	9.6	0.143	0.065
1	1	2	0	0	0	255	9.4	0.142	0.064
1	1	2	0	0	0	255	9.7	0.143	0.066
1	1	2	0	0	0	255	9.5	0.142	0.064
1	1	2	0	0	0	255	9.5	0.142	0.065
1	1	2	0	0	0	255	9.8	0.143	0.067
1	1	1	0	0	0	255	19.7	0.142	0.066
1	1	1	0	0	0	255	19.4	0.142	0.064
1	1	1	0	0	0	255	19.3	0.142	0.064
1	1	1	0	0	0	255	18.6	0.142	0.064
1	1	1	0	0	0	255	20	0.143	0.068
1	2	2	52	59	59	255	13.2	0.146	0.074
1	2	2	60	66	66	255	13.4	0.146	0.074
1	2	2	18	139	139	255	26.3	0.171	0.128
1	2	1	44	96	96	255	17.1	0.154	0.091
1	2	1	24	83	83	255	15.4	0.149	0.082
1	2	1	21	135	135	255	25.5	0.169	0.125
1	2	2	33	90	90	255	13.2	0.15	0.083
1	2	2	51	46	46	255	10.2	0.143	0.066
1	2	1	56	94	94	255	13.6	0.152	0.086
1	2	2	53	69	69	255	11.3	0.146	0.073

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	2	1	28	73	73	255	11.7	0.147	0.075
1	2	2	18	137	137	255	21.1	0.17	0.123
1	2	2	141	93	93	255	13.5	0.152	0.085
1	2	1	92	85	85	255	30.8	0.152	0.092
1	2	1	31	69	69	255	26.8	0.147	0.08
1	2	2	53	81	81	255	29.8	0.15	0.087
1	2	1	47	87	87	255	31.8	0.152	0.092
1	2	2	19	96	96	255	34.7	0.155	0.1
1	2	1	33	86	86	255	29.9	0.152	0.092
1	2	2	31	85	85	255	30.8	0.152	0.09
1	2	1	45	62	62	255	13.3	0.146	0.074
1	2	1	109	67	67	255	13.6	0.146	0.074
1	2	2	23	102	102	255	18.1	0.155	0.094
1	2	2	21	55	55	255	12.7	0.144	0.069
1	2	2	31	95	95	255	16.9	0.153	0.089
1	2	1	23	85	85	255	12.7	0.149	0.08
1	2	2	38	92	92	255	13.4	0.151	0.084
1	2	2	62	60	60	255	10.7	0.144	0.069
1	2	2	47	75	75	255	11.7	0.147	0.075
1	2	2	68	73	73	255	11.6	0.147	0.075
1	2	2	33	85	85	255	12.7	0.149	0.081
1	2	2	22	56	56	255	10.5	0.144	0.068
1	2	2	46	86	86	255	13	0.15	0.08
1	2	1	30	53	53	255	25.2	0.145	0.076
1	2	1	39	75	75	255	28.6	0.149	0.084
1	2	1	35	63	63	255	25.9	0.146	0.077
1	2	1	25	67	67	255	26.3	0.147	0.079
1	2	1	30	78	78	255	29.5	0.15	0.087
1	3	2	39	76	76	255	14.5	0.148	0.078
1	3	2	122	90	90	255	16.1	0.151	0.085
1	3	2	9	195	195	255	47.3	0.204	0.195
1	3	1	56	122	122	255	22	0.163	0.111
1	3	1	17	120	120	255	21.9	0.162	0.11
1	3	1	16	165	165	255	35	0.186	0.158
1	3	2	13	115	115	255	16.9	0.159	0.101
1	3	2	35	95	95	255	13.7	0.152	0.086
1	3	1	46	112	112	255	16.2	0.158	0.099
1	3	2	39	95	95	255	13.9	0.152	0.087
1	3	1	16	95	95	255	13.9	0.152	0.087
1	3	2	18	188	188	255	36.2	0.199	0.182
1	3	2	71	123	123	255	18.3	0.163	0.109
1	3	1	45	105	105	255	39.6	0.158	0.106
1	3	1	19	107	107	255	38.1	0.159	0.108
1	3	2	73	108	108	255	38.5	0.159	0.108
1	3	1	46	101	101	255	36.6	0.157	0.103
1	3	2	26	106	106	255	37.9	0.158	0.106
1	3	1	45	123	123	255	39.3	0.166	0.119
1	3	2	32	115	115	255	41.4	0.163	0.115

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	3	1	50	97	97	255	17.1	0.154	0.091
1	3	1	85	85	85	255	15.5	0.15	0.084
1	3	2	25	126	126	255	23.2	0.165	0.117
1	3	2	16	75	75	255	14.3	0.147	0.077
1	3	2	21	125	125	255	23.1	0.165	0.116
1	3	1	35	105	105	255	15.2	0.155	0.093
1	3	2	31	105	105	255	15.2	0.155	0.093
1	3	2	31	97	97	255	14	0.153	0.087
1	3	2	25	89	89	255	13.1	0.15	0.083
1	3	2	50	100	100	255	14.4	0.154	0.089
1	3	2	51	110	110	255	16	0.157	0.098
1	3	2	17	80	80	255	12.1	0.148	0.077
1	3	2	83	107	107	255	15.7	0.156	0.094
1	3	1	50	83	83	255	30.6	0.151	0.089
1	3	1	36	94	94	255	33.9	0.154	0.097
1	3	1	43	90	90	255	32.4	0.153	0.093
1	3	1	31	92	92	255	32.6	0.154	0.095
1	3	1	32	100	100	255	36	0.157	0.102
1	4	2	34	88	88	255	16	0.151	0.086
1	4	2	44	105	105	255	18.7	0.156	0.097
1	4	2	18	175	175	255	38.3	0.192	0.171
1	4	1	25	143	143	255	27.8	0.173	0.133
1	4	1	14	145	145	255	28.5	0.175	0.135
1	4	1	38	178	178	255	40.6	0.193	0.173
1	4	2	19	127	127	255	19	0.165	0.113
1	4	2	27	118	118	255	17.3	0.161	0.104
1	4	1	49	124	124	255	18.5	0.163	0.11
1	4	2	39	105	105	255	15.1	0.155	0.093
1	4	1	17	103	103	255	14.9	0.155	0.092
1	4	2	32	168	168	255	29.6	0.187	0.158
1	4	2	105	144	144	255	23	0.173	0.13
1	4	1	29	132	132	255	48.1	0.169	0.131
1	4	1	20	119	119	255	42.4	0.164	0.119
1	4	2	26	123	123	255	44.9	0.165	0.122
1	4	1	37	114	114	255	41.1	0.161	0.113
1	4	2	13	120	120	255	43.7	0.164	0.119
1	4	1	31	144	144	255	52.1	0.176	0.143
1	4	2	25	128	128	255	47.2	0.168	0.128
1	4	1	33	114	114	255	20.5	0.16	0.105
1	4	1	98	102	102	255	18.2	0.156	0.096
1	4	2	33	136	136	255	25.8	0.17	0.125
1	4	2	14	90	90	255	16.2	0.151	0.085
1	4	2	24	135	135	255	25.6	0.169	0.123
1	4	1	20	135	135	255	20.8	0.168	0.119
1	4	2	25	126	126	255	18.9	0.164	0.111
1	4	2	38	116	116	255	17	0.16	0.103
1	4	2	31	99	99	255	14.3	0.154	0.09
1	4	2	59	116	116	255	17	0.16	0.102

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	4	2	83	145	145	255	23.1	0.174	0.131
1	4	2	27	88	88	255	13	0.15	0.082
1	4	2	45	123	123	255	18.6	0.163	0.108
1	4	1	37	103	103	255	36.8	0.157	0.103
1	4	1	55	112	112	255	40.1	0.161	0.111
1	4	1	26	105	105	255	37.6	0.158	0.106
1	4	1	41	119	119	255	42.8	0.164	0.119
1	4	1	32	117	117	255	42.5	0.164	0.117
1	5	2	43	109	109	255	19.3	0.158	0.1
1	5	2	36	128	128	255	23.6	0.166	0.117
1	5	2	16	162	162	255	33.9	0.184	0.154
1	5	1	56	162	162	255	33.5	0.184	0.155
1	5	1	30	180	180	255	41.1	0.194	0.176
1	5	1	22	200	200	255	50.7	0.207	0.201
1	5	2	27	145	145	255	23.2	0.173	0.131
1	5	2	46	132	132	255	20.1	0.167	0.117
1	5	1	57	138	138	255	21.4	0.17	0.125
1	5	2	32	128	128	255	19.3	0.166	0.114
1	5	1	47	124	124	255	18.6	0.163	0.11
1	5	2	24	152	152	255	25	0.178	0.14
1	5	2	82	168	168	255	29.5	0.187	0.158
1	5	1	66	150	150	255	54.7	0.177	0.147
1	5	1	37	138	138	255	49.6	0.172	0.137
1	5	2	89	140	140	255	51.3	0.173	0.138
1	5	1	44	124	124	255	43.7	0.165	0.122
1	5	2	32	138	138	255	50.2	0.171	0.135
1	5	1	55	159	159	255	56.1	0.184	0.158
1	5	2	28	150	150	255	56.3	0.179	0.151
1	5	1	68	127	127	255	23.4	0.165	0.117
1	5	1	63	119	119	255	21.5	0.162	0.11
1	5	2	34	147	147	255	29	0.175	0.137
1	5	2	16	115	115	255	20.7	0.16	0.106
1	5	2	28	150	150	255	30.1	0.177	0.14
1	5	1	37	140	140	255	22.1	0.171	0.125
1	5	2	24	145	145	255	23.2	0.174	0.13
1	5	2	51	131	131	255	19.9	0.167	0.116
1	5	2	49	113	113	255	16.5	0.159	0.101
1	5	2	87	136	136	255	21.1	0.169	0.122
1	5	2	69	170	170	255	30.3	0.188	0.16
1	5	2	26	110	110	255	16	0.158	0.1
1	5	2	109	139	139	255	21.7	0.171	0.124
1	5	1	68	123	123	255	43.1	0.165	0.121
1	5	1	35	125	125	255	44	0.165	0.122
1	5	1	29	129	129	255	45.6	0.167	0.126
1	5	1	43	142	142	255	51.2	0.174	0.14
1	5	1	39	140	140	255	51.1	0.174	0.14
1	6	2	43	135	135	255	25.5	0.169	0.125
1	6	2	58	139	139	255	26.6	0.171	0.129

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	6	2	16	185	185	255	42.8	0.197	0.182
1	6	1	33	180	180	255	41.2	0.195	0.176
1	6	1	16	195	195	255	48.3	0.204	0.195
1	6	1	16	210	210	255	55.5	0.213	0.213
1	6	2	10	160	160	255	27.2	0.182	0.149
1	6	2	33	139	139	255	21.7	0.171	0.125
1	6	1	38	163	163	255	28.3	0.184	0.152
1	6	2	49	153	153	255	25.2	0.178	0.14
1	6	1	22	132	132	255	20.1	0.167	0.117
1	6	2	22	179	179	255	33.1	0.194	0.172
1	6	2	153	185	185	255	35.5	0.197	0.178
1	6	1	46	167	167	255	68.3	0.188	0.17
1	6	1	19	162	162	255	65.4	0.185	0.165
1	6	2	30	149	149	255	58.5	0.178	0.149
1	6	1	50	134	134	255	50.2	0.17	0.133
1	6	2	35	157	157	255	63.4	0.182	0.158
1	6	1	26	184	184	255	77.3	0.199	0.19
1	6	2	28	175	175	255	75.5	0.193	0.179
1	6	1	41	141	141	255	27.1	0.173	0.132
1	6	1	62	135	135	255	25.5	0.17	0.125
1	6	2	24	165	165	255	35.3	0.185	0.158
1	6	2	14	135	135	255	25.6	0.169	0.124
1	6	2	30	150	150	255	30	0.177	0.14
1	6	1	22	165	165	255	29	0.185	0.153
1	6	2	18	175	175	255	32	0.191	0.165
1	6	2	48	137	137	255	21.1	0.169	0.122
1	6	2	47	136	136	255	21	0.169	0.122
1	6	2	22	144	144	255	23	0.174	0.131
1	6	2	51	185	185	255	35.1	0.197	0.179
1	6	2	14	125	125	255	187	0.164	0.111
1	6	2	44	156	156	255	26.6	0.18	0.142
1	6	1	24	141	141	255	53.7	0.173	0.14
1	6	1	32	139	139	255	52.9	0.173	0.138
1	6	1	31	141	141	255	54.1	0.174	0.14
1	6	1	34	162	162	255	65.4	0.186	0.164
1	6	1	21	148	148	255	58	0.179	0.15
1	7	2	29	159	159	255	33	0.182	0.152
1	7	2	35	160	160	255	33.4	0.182	0.152
1	7	2	21	211	211	255	55.4	0.213	0.215
1	7	1	82	198	198	255	49.2	0.205	0.198
1	7	1	22	217	217	255	60	0.217	0.221
1	7	1	13	225	225	255	64.5	0.222	0.232
1	7	2	11	195	195	255	39.6	0.203	0.189
1	7	2	25	160	160	255	27.2	0.182	0.148
1	7	1	33	197	197	255	40.1	0.204	0.193
1	7	2	26	186	186	255	35.8	0.198	0.179
1	7	2	19	206	206	255	43.5	0.21	0.204
1	7	2	60	209	209	255	45.3	0.212	0.208

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	7	1	28	190	190	255	82.6	0.201	0.198
1	7	1	14	195	195	255	86.2	0.204	0.203
1	7	2	44	160	160	255	63.2	0.183	0.161
1	7	1	37	147	147	255	55.1	0.176	0.146
1	7	2	10	179	179	255	76.7	0.194	0.183
1	7	1	35	209	209	255	94.8	0.213	0.219
1	7	2	12	190	190	255	84.3	0.201	0.197
1	7	1	44	159	159	255	32.9	0.182	0.151
1	7	1	88	154	154	255	31.1	0.18	0.146
1	7	2	66	186	186	255	43.8	0.198	0.184
1	7	2	16	160	160	255	33.5	0.182	0.151
1	7	2	27	160	160	255	33.5	0.183	0.152
1	7	1	31	185	185	255	35.8	0.197	0.177
1	7	2	14	193	193	255	38.8	0.202	0.187
1	7	2	40	154	154	255	25.5	0.179	0.141
1	7	2	58	170	170	255	30.3	0.188	0.159
1	7	2	89	165	165	255	28.8	0.185	0.154
1	7	2	42	205	205	255	43.1	0.21	0.203
1	7	2	16	145	145	255	23.2	0.174	0.132
1	7	2	61	185	185	255	36.5	0.197	0.177
1	7	1	33	149	149	255	56.2	0.177	0.148
1	7	1	43	148	148	255	55.7	0.177	0.147
1	7	1	29	167	167	255	67.8	0.187	0.169
1	7	1	30	190	190	255	83.1	0.201	0.196
1	7	1	30	165	165	255	66.2	0.187	0.168
1	8	2	34	195	195	255	44.7	0.203	0.195
1	8	2	19	179	179	255	40.4	0.194	0.176
1	8	2	15	225	225	255	63.2	0.222	0.233
1	8	1	21	216	216	255	59	0.217	0.22
1	8	1	23	229	229	255	66.6	0.225	0.236
1	8	1	15	235	235	255	69.2	0.229	0.244
1	8	2	5	215	215	255	48	0.215	0.214
1	8	2	25	184	184	255	35	0.196	0.176
1	8	1	21	227	227	255	54.1	0.223	0.23
1	8	2	45	209	209	255	45.3	0.212	0.208
1	8	1	25	175	175	255	32	0.191	0.166
1	8	2	10	231	231	255	55.7	0.226	0.235
1	8	2	99	226	226	255	52.9	0.223	0.229
1	8	1	16	215	215	255	107	0.215	0.227
1	8	1	16	216	216	255	108	0.216	0.228
1	8	2	29	196	196	255	93.1	0.204	0.205
1	8	1	52	169	169	255	71.8	0.189	0.172
1	8	2	18	195	195	255	92.3	0.203	0.203
1	8	1	20	232	232	255	120	0.227	0.246
1	8	2	24	214	214	255	106	0.216	0.226
1	8	1	90	200	200	255	50.3	0.206	0.201
1	8	1	54	199	199	255	49.5	0.206	0.2
1	8	2	24	211	211	255	55.9	0.214	0.215

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	8	2	17	195	195	255	48.4	0.203	0.194
1	8	2	29	180	180	255	41.6	0.194	0.176
1	8	1	28	210	210	255	46.2	0.212	0.208
1	8	2	24	214	214	255	47.7	0.215	0.213
1	8	2	38	175	175	255	31.9	0.191	0.166
1	8	2	43	199	199	255	41	0.206	0.195
1	8	2	39	191	191	255	37.5	0.201	0.186
1	8	2	49	230	230	255	54.8	0.225	0.234
1	8	2	32	183	183	255	34.8	0.196	0.176
1	8	2	57	211	211	255	47.6	0.214	0.209
1	8	1	28	183	183	255	82.1	0.196	0.189
1	8	1	40	167	167	255	70.3	0.187	0.17
1	8	1	23	192	192	255	89.8	0.201	0.199
1	8	1	27	217	217	255	109	0.218	0.229
1	8	1	23	200	200	255	95.3	0.207	0.21
1	9	2	0	255	255	255	69.5	0.237	0.265
1	9	2	0	255	255	255	68	0.238	0.265
1	9	2	0	255	255	255	69.5	0.239	0.264
1	9	1	0	255	255	255	69.6	0.238	0.267
1	9	1	0	255	255	255	69.1	0.238	0.265
1	9	1	0	255	255	255	68.3	0.239	0.265
1	9	2	0	255	255	255	57.5	0.238	0.26
1	9	2	0	255	255	255	56.4	0.238	0.26
1	9	1	0	255	255	255	56.6	0.239	0.263
1	9	2	0	255	255	255	56.4	0.238	0.261
1	9	1	0	255	255	255	56.4	0.238	0.261
1	9	2	0	255	255	255	59.2	0.239	0.259
1	9	2	0	255	255	255	59.4	0.238	0.259
1	9	1	0	255	255	255	104	0.235	0.265
1	9	1	0	255	255	255	119	0.237	0.271
1	9	2	0	255	255	255	116	0.235	0.268
1	9	1	0	255	255	255	123	0.236	0.271
1	9	2	0	255	255	255	122	0.237	0.27
1	9	1	0	255	255	255	114	0.239	0.27
1	9	2	0	255	255	255	115	0.237	0.269
1	9	1	0	255	255	255	69.1	0.237	0.265
1	9	1	0	255	255	255	67.8	0.237	0.265
1	9	2	0	255	255	255	69.6	0.238	0.266
1	9	2	0	255	255	255	69.9	0.238	0.266
1	9	2	0	255	255	255	67.5	0.239	0.265
1	9	1	0	255	255	255	57.5	0.238	0.26
1	9	2	0	255	255	255	56.8	0.239	0.259
1	9	2	0	255	255	255	60	0.238	0.26
1	9	2	0	255	255	255	56.7	0.238	0.26
1	9	2	0	255	255	255	57.1	0.238	0.259
1	9	2	0	255	255	255	56.7	0.238	0.26
1	9	2	0	255	255	255	59.2	0.238	0.261
1	9	2	0	255	255	255	57.3	0.239	0.262

Color	Seq	Hyst	Time	R	G	B	Y	x	y
1	9	1	0	255	255	255	123	0.236	0.27
1	9	1	0	255	255	255	123	0.236	0.271
1	9	1	0	255	255	255	119	0.236	0.27
1	9	1	0	255	255	255	117	0.238	0.27
1	9	1	0	255	255	255	121	0.238	0.27
2	1	2	0	0	255	0	55.7	0.227	0.645
2	1	2	0	0	255	0	55.1	0.228	0.642
2	1	2	0	0	255	0	54.7	0.227	0.638
2	1	1	0	0	255	0	54.8	0.228	0.639
2	1	1	0	0	255	0	54.5	0.228	0.631
2	1	1	0	0	255	0	55	0.227	0.643
2	1	2	0	0	255	0	45.5	0.229	0.64
2	1	2	0	0	255	0	45.3	0.229	0.64
2	1	1	0	0	255	0	45.6	0.229	0.645
2	1	2	0	0	255	0	45.5	0.229	0.643
2	1	1	0	0	255	0	45.4	0.229	0.641
2	1	2	0	0	255	0	45.7	0.229	0.643
2	1	2	0	0	255	0	45.7	0.23	0.645
2	1	1	0	0	255	0	98.4	0.225	0.644
2	1	1	0	0	255	0	99.9	0.226	0.643
2	1	2	0	0	255	0	10	0.226	0.644
2	1	1	0	0	255	0	10.1	0.226	0.643
2	1	2	0	0	255	0	10	0.226	0.643
2	1	1	0	0	255	0	95.9	0.228	0.646
2	1	2	0	0	255	0	98.8	0.228	0.643
2	1	1	0	0	255	0	55.3	0.227	0.644
2	1	1	0	0	255	0	55	0.228	0.641
2	1	1	0	0	255	0	54.7	0.228	0.637
2	1	2	0	0	255	0	54.9	0.227	0.639
2	1	2	0	0	255	0	55.2	0.227	0.644
2	1	2	0	0	255	0	54.7	0.228	0.644
2	1	1	0	0	255	0	45.5	0.229	0.64
2	1	2	0	0	255	0	45.5	0.23	0.642
2	1	2	0	0	255	0	45.7	0.229	0.645
2	1	2	0	0	255	0	45.8	0.229	0.645
2	1	2	0	0	255	0	45.4	0.229	0.639
2	1	2	0	0	255	0	45.6	0.229	0.643
2	1	2	0	0	255	0	45.5	0.229	0.643
2	1	2	0	0	255	0	45.5	0.23	0.643
2	1	1	0	0	255	0	10	0.226	0.643
2	1	1	0	0	255	0	10.1	0.226	0.643
2	1	1	0	0	255	0	10.1	0.226	0.643
2	1	1	0	0	255	0	98.4	0.227	0.645
2	1	1	0	0	255	0	99.6	0.227	0.644
2	2	2	33	72	255	72	56	0.231	0.625
2	2	2	73	95	255	95	56.4	0.235	0.594
2	2	2	14	100	255	100	56.1	0.236	0.586
2	2	1	38	106	255	106	57.3	0.237	0.576

Color	Seq	Hyst	Time	R	G	B	Y	x	y
2	2	1	13	110	255	110	57.5	0.238	0.566
2	2	1	23	143	255	143	60.9	0.24	0.486
2	2	2	16	110	255	110	47.9	0.239	0.573
2	2	2	35	90	255	90	46.4	0.236	0.607
2	2	1	53	111	255	111	47.9	0.24	0.575
2	2	2	69	48	255	48	45.6	0.23	0.63
2	2	1	38	80	255	80	46.4	0.235	0.619
2	2	2	39	102	255	102	46.8	0.238	0.586
2	2	2	175	110	255	110	47.7	0.239	0.574
2	2	1	61	98	255	98	10.7	0.23	0.577
2	2	1	14	99	255	99	10.9	0.232	0.579
2	2	2	79	88	255	88	11	0.231	0.6
2	2	1	47	80	255	80	10.8	0.23	0.608
2	2	2	72	94	255	94	11	0.231	0.589
2	2	1	39	97	255	97	10.4	0.233	0.579
2	2	2	21	115	255	115	11	0.234	0.536
2	2	1	43	87	255	87	56.4	0.234	0.61
2	2	1	100	99	255	99	57.2	0.236	0.592
2	2	1	36	78	255	78	56.1	0.233	0.622
2	2	2	37	94	255	94	57.6	0.236	0.605
2	2	2	22	80	255	80	57.1	0.234	0.624
2	2	2	40	95	255	95	57.4	0.236	0.602
2	2	1	31	105	255	105	47.2	0.239	0.581
2	2	2	20	137	255	137	49.9	0.241	0.505
2	2	2	22	35	255	35	46.4	0.23	0.639
2	2	2	23	1	255	1	45.7	0.229	0.634
2	2	2	92	99	255	99	46.9	0.237	0.594
2	2	2	109	99	255	99	47.2	0.237	0.597
2	2	2	7	60	255	60	46	0.231	0.633
2	2	2	64	115	255	115	49.2	0.242	0.562
2	2	1	36	75	255	75	10.8	0.229	0.618
2	2	1	39	82	255	82	10.8	0.23	0.605
2	2	1	18	81	255	81	10.6	0.232	0.6
2	2	1	28	90	255	90	10.9	0.232	0.592
2	3	2	39	98	255	98	57.1	0.235	0.594
2	3	2	74	121	255	121	58.7	0.238	0.544
2	3	2	18	130	255	130	59	0.238	0.521
2	3	1	60	124	255	124	59	0.239	0.537
2	3	1	12	140	255	140	60.6	0.24	0.494
2	3	1	13	190	255	190	68.2	0.241	0.371
2	3	2	14	135	255	135	49.3	0.241	0.509
2	3	2	28	122	255	122	48	0.241	0.54
2	3	1	51	129	255	129	48.9	0.241	0.527
2	3	2	64	94	255	94	47	0.237	0.605
2	3	1	39	109	255	109	47.4	0.239	0.572
2	3	2	54	136	255	136	49.5	0.241	0.507
2	3	2	184	140	255	140	49.8	0.242	0.497
2	3	1	47	130	255	130	11.2	0.233	0.504

Color	Seq	Hyst	Time	R	G	B	Y	x	y
2	3	1	20	138	255	138	11.3	0.234	0.482
2	3	2	41	117	255	117	11.3	0.233	0.538
2	3	1	33	105	255	105	11	0.232	0.563
2	3	2	28	110	255	110	11.2	0.233	0.554
2	3	1	29	118	255	118	10.7	0.234	0.532
2	3	2	19	125	255	125	11.3	0.235	0.515
2	3	1	40	111	255	111	58	0.237	0.567
2	3	1	92	122	255	122	58.6	0.238	0.541
2	3	1	28	114	255	114	57.8	0.238	0.559
2	3	2	71	120	255	120	59	0.238	0.548
2	3	2	11	95	255	95	57.9	0.236	0.604
2	3	2	24	125	255	125	59.2	0.239	0.533
2	3	1	27	120	255	120	48.9	0.241	0.549
2	3	2	20	155	255	155	51.6	0.242	0.455
2	3	2	25	90	255	90	47.2	0.237	0.613
2	3	2	26	95	255	95	46.5	0.237	0.6
2	3	2	40	124	255	124	48.1	0.24	0.536
2	3	2	93	125	255	125	48.5	0.241	0.535
2	3	2	22	104	255	104	47.5	0.239	0.585
2	3	2	87	147	255	147	51.8	0.243	0.477
2	3	1	41	121	255	121	11.3	0.233	0.528
2	3	1	43	95	255	95	11	0.231	0.586
2	3	1	73	87	255	87	10.9	0.231	0.6
2	3	1	34	115	255	115	11.1	0.234	0.538
2	3	1	26	110	255	110	11	0.234	0.544
2	4	2	32	113	255	113	58.2	0.237	0.564
2	4	2	69	140	255	140	60.9	0.239	0.495
2	4	2	21	150	255	150	61.1	0.24	0.468
2	4	1	57	138	255	138	61.2	0.24	0.502
2	4	1	12	160	255	160	63.8	0.24	0.443
2	4	1	10	210	255	210	72.9	0.241	0.332
2	4	2	13	150	255	150	51.2	0.241	0.469
2	4	2	35	144	255	144	50.2	0.241	0.485
2	4	1	32	142	255	142	50.5	0.242	0.493
2	4	2	43	111	255	111	47	0.239	0.564
2	4	1	33	128	255	128	48.9	0.241	0.528
2	4	2	77	159	255	159	51.4	0.242	0.443
2	4	2	129	157	255	157	51.6	0.242	0.45
2	4	1	18	154	255	154	11.6	0.234	0.444
2	4	1	19	151	255	151	11.5	0.234	0.452
2	4	2	37	135	255	135	11.6	0.234	0.495
2	4	1	27	120	255	120	11.3	0.233	0.531
2	4	2	61	131	255	131	11.5	0.234	0.504
2	4	1	39	138	255	138	11.1	0.235	0.484
2	4	2	18	140	255	140	11.6	0.235	0.479
2	4	1	35	129	255	129	59.8	0.238	0.525
2	4	1	40	135	255	135	59.6	0.239	0.506
2	4	1	29	134	255	134	60	0.239	0.512

Color	Seq	Hyst	Time	R	G	B	Y	x	y
2	4	2	37	141	255	141	61.4	0.24	0.493
2	4	2	14	110	255	110	58.4	0.238	0.571
2	4	2	16	150	255	150	61.9	0.24	0.468
2	4	1	43	130	255	130	49.1	0.241	0.522
2	4	2	20	178	255	178	54.3	0.241	0.396
2	4	2	22	114	255	114	48.1	0.24	0.565
2	4	2	45	106	255	106	47.3	0.239	0.581
2	4	2	38	138	255	138	50.1	0.241	0.502
2	4	2	35	145	255	145	50.3	0.242	0.481
2	4	2	21	128	255	128	48.7	0.241	0.527
2	4	2	41	164	255	164	53.6	0.243	0.431
2	4	1	35	149	255	149	11.7	0.234	0.458
2	4	1	28	105	255	105	11.1	0.232	0.565
2	4	1	34	103	255	103	11.1	0.232	0.568
2	4	1	17	127	255	127	11.2	0.234	0.509
2	4	1	27	139	255	139	11.6	0.235	0.479
2	5	2	30	142	255	142	60.8	0.239	0.489
2	5	2	45	170	255	170	64.4	0.24	0.417
2	5	2	13	170	255	170	64.3	0.24	0.417
2	5	1	100	161	255	161	63.7	0.241	0.441
2	5	1	22	195	255	195	69.5	0.24	0.361
2	5	1	16	228	255	228	76.5	0.24	0.302
2	5	2	18	165	255	165	52.9	0.242	0.428
2	5	2	39	161	255	161	51.9	0.242	0.438
2	5	1	26	172	255	172	53.2	0.242	0.411
2	5	2	30	145	255	145	50.1	0.242	0.48
2	5	1	27	158	255	158	51.7	0.241	0.447
2	5	2	32	185	255	185	54.9	0.242	0.379
2	5	2	198	180	255	180	54.8	0.241	0.393
2	5	1	22	190	255	190	12.2	0.236	0.37
2	5	1	17	180	255	180	12.2	0.236	0.392
2	5	2	39	169	255	169	12	0.235	0.416
2	5	1	26	145	255	145	11.5	0.234	0.473
2	5	2	22	151	255	151	11.6	0.235	0.459
2	5	1	29	164	255	164	11.3	0.237	0.426
2	5	2	14	165	255	165	11.7	0.237	0.421
2	5	1	30	149	255	149	61.6	0.239	0.47
2	5	1	102	148	255	148	61.3	0.24	0.473
2	5	1	30	158	255	158	63.1	0.24	0.448
2	5	2	29	173	255	173	65.1	0.241	0.41
2	5	2	14	145	255	145	61	0.24	0.481
2	5	2	18	170	255	170	64.7	0.241	0.416
2	5	1	54	145	255	145	50.8	0.241	0.482
2	5	2	18	196	255	196	56.9	0.241	0.356
2	5	2	31	154	255	154	51.2	0.242	0.457
2	5	2	35	130	255	130	48.8	0.241	0.521
2	5	2	105	166	255	166	53	0.242	0.426
2	5	2	77	172	255	172	53.5	0.242	0.411

Color	Seq	Hyst	Time	R	G	B	Y	x	y
2	5	2	18	155	255	155	51.5	0.242	0.456
2	5	2	66	187	255	187	56.9	0.242	0.376
2	5	1	48	187	255	187	12.5	0.236	0.378
2	5	1	39	124	255	124	11.1	0.233	0.526
2	5	1	41	134	255	134	11.3	0.234	0.501
2	5	1	37	154	255	154	11.5	0.236	0.449
2	5	1	29	172	255	172	12	0.236	0.407
2	6	2	32	166	255	166	64.3	0.24	0.428
2	6	2	108	177	255	177	65.4	0.24	0.399
2	6	2	14	180	255	180	65.9	0.24	0.394
2	6	1	34	173	255	173	65.6	0.241	0.411
2	6	1	12	200	255	200	70.6	0.24	0.351
2	6	1	22	231	255	231	77.5	0.24	0.298
2	6	2	18	180	255	180	54.4	0.241	0.39
2	6	2	37	176	255	176	53.9	0.241	0.401
2	6	1	30	185	255	185	55.7	0.242	0.381
2	6	1	38	169	255	169	53	0.241	0.417
2	6	2	25	195	255	195	56.2	0.241	0.357
2	6	2	110	195	255	195	57.2	0.241	0.359
2	6	1	23	199	255	199	129	0.236	0.352
2	6	1	29	196	255	196	128	0.237	0.358
2	6	2	68	183	255	183	126	0.236	0.384
2	6	1	42	147	255	147	117	0.234	0.464
2	6	2	42	159	255	159	120	0.235	0.437
2	6	1	21	183	255	183	121	0.237	0.383
2	6	2	15	180	255	180	124	0.236	0.387
2	6	1	28	162	255	162	63.3	0.24	0.436
2	6	1	74	152	255	152	61.6	0.24	0.462
2	6	1	18	176	255	176	65.5	0.24	0.403
2	6	2	29	185	255	185	67.4	0.241	0.381
2	6	2	15	165	255	165	64.6	0.24	0.43
2	6	2	24	175	255	175	65.7	0.241	0.404
2	6	1	22	160	255	160	52.3	0.241	0.442
2	6	2	20	212	255	212	59	0.241	0.325
2	6	2	50	181	255	181	54.9	0.241	0.39
2	6	2	48	148	255	148	50	0.242	0.472
2	6	2	31	177	255	177	54.3	0.242	0.398
2	6	2	42	190	255	190	55.2	0.242	0.367
2	6	2	25	172	255	172	53.4	0.242	0.411
2	6	2	106	201	255	201	58.5	0.242	0.344
2	6	1	21	206	255	206	134	0.236	0.341
2	6	1	31	141	255	141	117	0.234	0.48
2	6	1	60	147	255	147	118	0.234	0.464
2	6	1	21	178	255	178	123	0.237	0.391
2	6	1	15	185	255	185	126	0.237	0.378
2	7	2	31	196	255	196	68.7	0.24	0.359
2	7	2	50	191	255	191	68.3	0.24	0.369
2	7	2	9	195	255	195	68.5	0.24	0.361

Color	Seq	Hyst	Time	R	G	B	Y	x	y
2	7	1	35	199	255	199	69.7	0.24	0.353
2	7	1	7	215	255	215	73.6	0.24	0.324
2	7	1	19	236	255	236	78.9	0.24	0.291
2	7	2	16	205	255	205	58.8	0.24	0.337
2	7	2	47	182	255	182	54.8	0.241	0.386
2	7	1	20	207	255	207	58.6	0.241	0.335
2	7	2	39	183	255	183	54.7	0.242	0.383
2	7	1	25	185	255	185	55.2	0.241	0.379
2	7	2	23	213	255	213	60.2	0.241	0.323
2	7	2	172	218	255	218	60.4	0.241	0.315
2	7	1	18	215	255	215	131	0.237	0.326
2	7	1	12	213	255	213	130	0.235	0.328
2	7	2	40	203	255	203	130	0.236	0.348
2	7	1	29	167	255	167	119	0.235	0.419
2	7	2	9	174	255	174	121	0.235	0.405
2	7	1	22	201	255	201	124	0.238	0.35
2	7	2	12	205	255	205	130	0.238	0.344
2	7	1	33	178	255	178	65.2	0.24	0.397
2	7	1	51	165	255	165	63.3	0.24	0.428
2	7	1	22	190	255	190	67	0.241	0.37
2	7	2	23	203	255	203	70.5	0.24	0.345
2	7	2	16	185	255	185	67.7	0.24	0.382
2	7	2	15	195	255	195	69.2	0.241	0.36
2	7	1	19	180	255	180	54.8	0.241	0.39
2	7	2	32	219	255	219	60.7	0.241	0.313
2	7	2	43	202	255	202	58.4	0.241	0.344
2	7	2	41	178	255	178	53.7	0.242	0.395
2	7	2	43	196	255	196	56.9	0.241	0.355
2	7	2	47	210	255	210	59.7	0.241	0.329
2	7	2	15	190	255	190	55.7	0.242	0.368
2	7	2	68	215	255	215	61	0.241	0.318
2	7	1	48	227	255	227	140	0.237	0.309
2	7	1	29	160	255	160	118	0.235	0.436
2	7	1	71	177	255	177	122	0.236	0.398
2	7	1	25	204	255	204	128	0.238	0.344
2	7	1	27	205	255	205	130	0.238	0.344
2	8	2	25	228	255	228	76.2	0.239	0.303
2	8	2	87	213	255	213	72.4	0.24	0.327
2	8	2	9	210	255	210	70.4	0.24	0.332
2	8	1	28	214	255	214	73.9	0.24	0.325
2	8	1	15	230	255	230	77.4	0.24	0.3
2	8	1	18	241	255	241	79.9	0.24	0.284
2	8	2	12	215	255	215	60.7	0.24	0.32
2	8	2	44	204	255	204	57.8	0.241	0.339
2	8	1	15	226	255	226	63	0.24	0.302
2	8	2	46	213	255	213	59.7	0.241	0.323
2	8	1	28	206	255	206	58.8	0.241	0.336
2	8	2	57	225	255	225	61.2	0.241	0.303

Color	Seq	Hyst	Time	R	G	B	Y	x	y
2	8	2	238	231	255	231	63.5	0.241	0.295
2	8	1	51	236	255	236	140	0.237	0.295
2	8	1	7	228	255	228	137	0.236	0.305
2	8	2	32	224	255	224	140	0.237	0.313
2	8	1	34	190	255	190	128	0.236	0.37
2	8	2	89	196	255	196	131	0.236	0.359
2	8	1	19	228	255	228	135	0.239	0.306
2	8	2	16	220	255	220	135	0.238	0.319
2	8	1	37	203	255	203	70.4	0.24	0.345
2	8	1	55	181	255	181	66.3	0.24	0.39
2	8	1	30	211	255	211	70.9	0.24	0.33
2	8	2	41	223	255	223	74.7	0.24	0.311
2	8	2	21	205	255	205	71.4	0.24	0.341
2	8	2	22	210	255	210	72.7	0.24	0.332
2	8	1	23	200	255	200	57.9	0.241	0.347
2	8	2	14	234	255	234	64.7	0.24	0.29
2	8	2	55	206	255	206	59.1	0.241	0.337
2	8	2	50	209	255	209	58.6	0.241	0.33
2	8	2	109	217	255	217	60.3	0.241	0.316
2	8	2	47	232	255	232	63.3	0.24	0.293
2	8	2	21	215	255	215	60.4	0.241	0.32
2	8	2	68	230	255	230	64.3	0.24	0.294
2	8	1	43	238	255	238	145	0.238	0.294
2	8	1	22	180	255	180	126	0.235	0.389
2	8	1	22	206	255	206	134	0.236	0.342
2	8	1	24	232	255	232	138	0.239	0.301
2	8	1	26	220	255	220	135	0.238	0.319
2	9	2	0	255	255	255	70.8	0.237	0.265
2	9	2	0	255	255	255	69.4	0.238	0.266
2	9	2	0	255	255	255	68.2	0.238	0.266
2	9	1	0	255	255	255	69.6	0.239	0.267
2	9	1	0	255	255	255	69.9	0.239	0.267
2	9	1	0	255	255	255	69.5	0.239	0.266
2	9	2	0	255	255	255	57.7	0.238	0.261
2	9	2	0	255	255	255	57.5	0.238	0.26
2	9	1	0	255	255	255	57.6	0.238	0.262
2	9	2	0	255	255	255	57.4	0.238	0.261
2	9	1	0	255	255	255	57.8	0.238	0.261
2	9	2	0	255	255	255	56.5	0.238	0.26
2	9	2	0	255	255	255	57.4	0.238	0.262
2	9	1	0	255	255	255	115	0.237	0.269
2	9	1	0	255	255	255	122	0.237	0.271
2	9	2	0	255	255	255	125	0.237	0.272
2	9	1	0	255	255	255	126	0.236	0.272
2	9	2	0	255	255	255	125	0.237	0.272
2	9	1	0	255	255	255	115	0.238	0.27
2	9	2	0	255	255	255	121	0.238	0.27
2	9	1	0	255	255	255	70	0.238	0.266

Color	Seq	Hyst	Time	R	G	B	Y	x	y
2	9	1	0	255	255	255	69	0.238	0.265
2	9	1	0	255	255	255	69.3	0.238	0.267
2	9	2	0	255	255	255	69.3	0.239	0.267
2	9	2	0	255	255	255	70.8	0.239	0.265
2	9	2	0	255	255	255	70.4	0.239	0.265
2	9	1	0	255	255	255	57.7	0.238	0.261
2	9	2	0	255	255	255	57.9	0.238	0.261
2	9	2	0	255	255	255	57.9	0.238	0.261
2	9	2	0	255	255	255	57.9	0.238	0.261
2	9	2	0	255	255	255	57.8	0.238	0.261
2	9	2	0	255	255	255	57.2	0.238	0.262
2	9	2	0	255	255	255	58.1	0.238	0.261
2	9	2	0	255	255	255	59.4	0.239	0.259
2	9	1	0	255	255	255	125	0.236	0.272
2	9	1	0	255	255	255	126	0.236	0.272
2	9	1	0	255	255	255	126	0.237	0.272
2	9	1	0	255	255	255	120	0.238	0.27
2	9	1	0	255	255	255	123	0.238	0.27
3	1	2	0	255	0	0	16	0.574	0.338
3	1	2	0	255	0	0	16	0.578	0.338
3	1	2	0	255	0	0	15.9	0.594	0.334
3	1	1	0	255	0	0	16.1	0.586	0.334
3	1	1	0	255	0	0	16.1	0.584	0.333
3	1	1	0	255	0	0	16.1	0.588	0.334
3	1	2	0	255	0	0	13.4	0.599	0.334
3	1	2	0	255	0	0	13.5	0.592	0.334
3	1	1	0	255	0	0	13.3	0.597	0.335
3	1	2	0	255	0	0	13.4	0.598	0.334
3	1	1	0	255	0	0	13.4	0.598	0.334
3	1	2	0	255	0	0	13.4	0.599	0.335
3	1	1	0	255	0	0	26.6	0.599	0.336
3	1	1	0	255	0	0	27.4	0.585	0.335
3	1	2	0	255	0	0	27	0.597	0.339
3	1	1	0	255	0	0	27.1	0.593	0.339
3	1	2	0	255	0	0	27.1	0.236	0.272
3	1	1	0	255	0	0	26.6	0.59	0.333
3	1	2	0	255	0	0	26.7	0.6	0.337
3	1	1	0	255	0	0	16.1	0.59	0.337
3	1	1	0	255	0	0	16.1	0.594	0.337
3	1	1	0	255	0	0	16.1	0.588	0.333
3	1	2	0	255	0	0	15.9	0.597	0.337
3	1	1	0	255	0	0	13.4	0.599	0.334
3	1	2	0	255	0	0	13.4	0.595	0.334
3	1	2	0	255	0	0	13.3	0.604	0.335
3	1	2	0	255	0	0	13.4	0.598	0.334
3	1	2	0	255	0	0	13.4	0.598	0.336
3	1	2	0	255	0	0	13.4	0.601	0.335
3	1	2	0	255	0	0	13.4	0.604	0.335

Color	Seq	Hyst	Time	R	G	B	Y	x	y
3	1	2	0	255	0	0	13.5	0.582	0.335
3	1	1	0	255	0	0	27	0.597	0.338
3	1	1	0	255	0	0	27.1	0.591	0.337
3	1	1	0	255	0	0	27.1	0.592	0.338
3	1	1	0	255	0	0	26.7	0.594	0.337
3	1	1	0	255	0	0	26.9	0.594	0.334
3	2	2	48	255	40	40	17.5	0.597	0.342
3	2	2	68	255	13	13	17.3	0.599	0.339
3	2	2	11	255	120	120	25.8	0.456	0.337
3	2	1	37	255	88	88	20.7	0.55	0.352
3	2	1	21	255	80	80	20	0.561	0.35
3	2	1	11	255	180	180	44	0.321	0.297
3	2	2	33	255	75	75	15.9	0.569	0.346
3	2	2	23	255	88	88	17	0.542	0.346
3	2	1	42	255	92	92	17.3	0.547	0.349
3	2	2	50	255	57	57	15	0.597	0.343
3	2	1	18	255	78	78	16.1	0.57	0.348
3	2	2	56	255	80	80	16.4	0.561	0.347
3	2	2	127	255	97	97	17.9	0.531	0.347
3	2	1	33	255	75	75	36.8	0.536	0.349
3	2	1	17	255	81	81	37.9	0.525	0.349
3	2	2	69	255	59	59	34.2	0.573	0.352
3	2	1	34	255	78	78	37.8	0.534	0.353
3	2	2	44	255	75	75	37.1	0.545	0.354
3	2	1	39	255	81	81	37.7	0.526	0.349
3	2	2	25	255	70	70	36.5	0.548	0.352
3	2	1	32	255	49	49	17.8	0.584	0.342
3	2	1	82	255	62	62	16.5	0.594	0.337
3	2	1	10	255	60	60	18.2	0.59	0.346
3	2	2	10	255	75	75	19.4	0.575	0.351
3	2	1	16	255	95	95	17.7	0.534	0.346
3	2	2	26	255	73	73	15.8	0.577	0.347
3	2	2	31	255	106	106	18.9	0.508	0.343
3	2	2	45	255	73	73	15.9	0.564	0.345
3	2	2	95	255	73	73	15.8	0.574	0.346
3	2	2	64	255	80	80	16.4	0.565	0.349
3	2	2	32	255	83	83	16.5	0.561	0.348
3	2	2	61	255	96	96	17.6	0.532	0.346
3	2	1	46	255	38	38	32	0.592	0.346
3	2	1	31	255	74	74	37	0.547	0.354
3	2	1	26	255	73	73	36.8	0.544	0.353
3	2	1	17	255	64	64	35	0.562	0.351
3	2	1	22	255	70	70	36.6	0.546	0.351
3	3	2	20	255	80	80	19.9	0.557	0.352
3	3	2	53	255	83	83	20.3	0.553	0.352
3	3	2	16	255	150	150	33.3	0.381	0.317
3	3	1	35	255	109	109	23.9	0.49	0.343
3	3	1	13	255	115	115	24.9	0.468	0.339

Color	Seq	Hyst	Time	R	G	B	Y	x	y
3	3	1	10	255	210	210	57.7	0.279	0.282
3	3	2	16	255	90	90	17.1	0.55	0.348
3	3	2	21	255	98	98	18	0.529	0.346
3	3	1	48	255	117	117	20.6	0.477	0.338
3	3	2	41	255	85	85	16.8	0.555	0.348
3	3	1	20	255	98	98	18	0.527	0.346
3	3	2	17	255	120	120	21.2	0.464	0.335
3	3	2	127	255	121	121	21.2	0.46	0.334
3	3	1	32	255	101	101	43.6	0.47	0.34
3	3	1	15	255	126	126	53	0.412	0.327
3	3	2	49	255	80	80	38.3	0.531	0.353
3	3	1	49	255	101	101	44.3	0.48	0.346
3	3	2	60	255	95	95	42.3	0.497	0.349
3	3	1	37	255	117	117	48.6	0.436	0.332
3	3	2	22	255	95	95	42.6	0.486	0.344
3	3	1	54	255	87	87	20.6	0.539	0.35
3	3	1	58	255	83	83	20.3	0.545	0.35
3	3	1	20	255	100	100	22.5	0.505	0.344
3	3	2	11	255	100	100	22.5	0.516	0.349
3	3	1	11	255	125	125	22.2	0.454	0.333
3	3	2	22	255	118	118	20.7	0.475	0.337
3	3	2	48	255	121	121	21.2	0.463	0.334
3	3	2	31	255	94	94	17.5	0.537	0.347
3	3	2	73	255	96	96	17.8	0.532	0.346
3	3	2	21	255	105	105	19	0.502	0.342
3	3	2	23	255	105	105	18.9	0.508	0.343
3	3	2	38	255	119	119	20.9	0.471	0.337
3	3	1	36	255	63	63	35.1	0.562	0.353
3	3	1	25	255	90	90	40.8	0.51	0.351
3	3	1	77	255	92	92	41.4	0.502	0.349
3	3	1	20	255	108	108	46.5	0.456	0.337
3	3	1	16	255	90	90	41.1	0.502	0.346
3	4	2	28	255	103	103	22.8	0.505	0.348
3	4	2	109	255	101	101	22.7	0.513	0.349
3	4	2	10	255	170	170	40	0.338	0.303
3	4	1	26	255	128	128	27.7	0.438	0.332
3	4	1	21	255	140	140	31.3	0.407	0.325
3	4	1	24	255	221	221	63.8	0.268	0.277
3	4	2	30	255	99	99	18.1	0.525	0.346
3	4	2	29	255	112	112	19.9	0.488	0.34
3	4	1	27	255	139	139	24.9	0.416	0.323
3	4	2	46	255	101	101	18.5	0.519	0.345
3	4	2	17	255	145	145	26.2	0.397	0.318
3	4	2	99	255	135	135	23.9	0.424	0.325
3	4	1	36	255	118	118	49.5	0.433	0.332
3	4	1	17	255	148	148	63.2	0.364	0.314
3	4	2	45	255	98	98	43	0.489	0.347
3	4	1	46	255	125	125	63.1	0.416	0.331

Color	Seq	Hyst	Time	R	G	B	Y	x	y
3	4	2	58	255	126	126	53.7	0.414	0.331
3	4	1	26	255	142	142	59.7	0.377	0.317
3	4	2	19	255	120	120	51	0.424	0.33
3	4	1	57	255	119	119	25.8	0.459	0.339
3	4	1	58	255	103	103	22.9	0.507	0.348
3	4	1	19	255	118	118	25.6	0.466	0.339
3	4	2	13	255	125	125	27.2	0.477	0.335
3	4	1	31	255	134	134	23.7	0.425	0.325
3	4	2	19	255	135	135	23.9	0.424	0.325
3	4	2	24	255	142	142	25.5	0.407	0.321
3	4	2	32	255	118	118	20.8	0.47	0.336
3	4	2	78	255	111	111	19.7	0.492	0.341
3	4	2	99	255	124	124	21.9	0.456	0.334
3	4	2	18	255	122	122	21.5	0.461	0.334
3	4	2	69	255	135	135	23.8	0.424	0.325
3	4	1	28	255	85	85	39.5	0.521	0.352
3	4	1	21	255	120	120	51.1	0.429	0.334
3	4	1	29	255	120	120	51.1	0.429	0.334
3	4	1	27	255	129	129	54.5	0.404	0.324
3	4	1	34	255	115	115	50	0.432	0.334
3	5	2	25	255	132	132	28.7	0.425	0.331
3	5	2	68	255	122	122	26.6	0.45	0.337
3	5	2	12	255	180	180	43.6	0.32	0.293
3	5	1	55	255	147	147	32.6	0.387	0.319
3	5	1	21	255	170	170	40.5	0.339	0.303
3	5	1	6	255	225	225	65.7	0.264	0.277
3	5	2	41	255	110	110	19.6	0.496	0.342
3	5	2	35	255	124	124	21.9	0.452	0.332
3	5	1	35	255	156	156	29	0.372	0.31
3	5	2	50	255	122	122	21.6	0.461	0.334
3	5	1	16	255	130	130	23	0.436	0.328
3	5	2	12	255	170	170	32.9	0.342	0.3
3	5	2	160	255	153	153	28	0.378	0.312
3	5	1	80	255	140	140	59.3	0.383	0.32
3	5	1	18	255	180	180	81.4	0.311	0.299
3	5	2	54	255	121	121	49.8	0.431	0.336
3	5	1	29	255	140	140	58.5	0.383	0.323
3	5	2	16	255	145	145	60.9	0.372	0.319
3	5	1	20	255	165	165	70.3	0.336	0.305
3	5	2	33	255	135	135	55.8	0.394	0.323
3	5	1	41	255	149	149	33.2	0.381	0.318
3	5	1	37	255	120	120	26	0.456	0.338
3	5	1	17	255	131	131	28.4	0.43	0.33
3	5	2	16	255	145	145	32.1	0.392	0.32
3	5	1	16	255	155	155	28.8	0.374	0.31
3	5	2	20	255	146	146	26.5	0.396	0.317
3	5	2	29	255	149	149	27	0.388	0.315
3	5	2	27	255	139	139	24.8	0.413	0.322

Color	Seq	Hyst	Time	R	G	B	Y	x	y
3	5	2	80	255	132	132	23.3	0.433	0.327
3	5	2	50	255	140	140	25.3	0.413	0.322
3	5	2	15	255	135	135	23.9	0.423	0.324
3	5	2	54	255	156	156	29.5	0.371	0.31
3	5	1	30	255	109	109	45.3	0.463	0.343
3	5	1	27	255	140	140	58.6	0.384	0.323
3	5	1	23	255	133	133	55.1	0.401	0.328
3	5	1	14	255	150	150	62.8	0.36	0.313
3	5	1	22	255	140	140	58.6	0.382	0.321
3	6	2	31	255	156	156	35.6	0.365	0.313
3	6	2	66	255	138	138	30.3	0.409	0.326
3	6	2	7	255	195	195	49.7	0.297	0.289
3	6	1	26	255	169	169	40.1	0.341	0.304
3	6	1	29	255	180	180	44.7	0.231	0.297
3	6	1	10	255	235	235	71.1	0.255	0.273
3	6	2	15	255	135	135	23.9	0.423	0.324
3	6	2	23	255	142	142	25.4	0.406	0.32
3	6	1	19	255	175	175	34.6	0.333	0.298
3	6	2	68	255	140	140	25.2	0.412	0.321
3	6	2	36	255	183	183	37.2	0.318	0.292
3	6	2	77	255	183	183	37.1	0.319	0.293
3	6	1	30	255	147	147	62.5	0.363	0.313
3	6	1	15	255	201	201	99.1	0.283	0.289
3	6	2	28	255	142	142	61.1	0.376	0.319
3	6	1	37	255	153	153	67	0.354	0.313
3	6	2	15	255	159	159	70.6	0.343	0.309
3	6	1	21	255	196	196	94	0.29	0.29
3	6	2	22	255	160	160	70.9	0.339	0.306
3	6	1	42	255	161	161	37.1	0.355	0.309
3	6	1	49	255	131	131	28.4	0.427	0.33
3	6	1	28	255	143	143	31.5	0.399	0.322
3	6	2	12	255	165	165	38.8	0.349	0.306
3	6	1	20	255	180	180	36.3	0.323	0.294
3	6	2	18	255	176	176	34.6	0.33	0.296
3	6	2	25	255	157	157	29.2	0.37	0.31
3	6	2	44	255	154	154	28.3	0.377	0.311
3	6	2	29	255	150	150	27.3	0.386	0.315
3	6	2	52	255	153	153	28	0.379	0.312
3	6	2	19	255	152	152	27.9	0.382	0.312
3	6	2	62	255	174	174	34.1	0.335	0.298
3	6	1	47	255	129	129	54	0.407	0.328
3	6	1	26	255	151	151	66.1	0.358	0.314
3	6	1	48	255	146	146	63	0.367	0.317
3	6	1	22	255	161	161	71.5	0.339	0.306
3	6	1	33	255	155	155	68.8	0.349	0.311
3	7	2	10	255	180	180	44	0.32	0.297
3	7	2	51	255	157	157	36	0.364	0.313
3	7	2	5	255	215	215	59.4	0.273	0.28

Color	Seq	Hyst	Time	R	G	B	Y	x	y
3	7	1	44	255	179	179	43.5	0.322	0.298
3	7	1	10	255	200	200	53.1	0.291	0.286
3	7	1	6	255	240	240	74.6	0.251	0.271
3	7	2	10	255	180	180	35.9	0.322	0.293
3	7	2	19	255	160	160	30	0.362	0.306
3	7	1	16	255	195	195	41.2	0.3	0.286
3	7	2	70	255	160	160	30.3	0.363	0.307
3	7	1	25	255	166	166	31.7	0.349	0.302
3	7	2	7	255	200	200	43.2	0.293	0.282
3	7	2	86	255	209	209	46.8	0.281	0.279
3	7	1	49	255	170	170	74.3	0.325	0.302
3	7	1	9	255	219	219	112	0.265	0.283
3	7	2	67	255	173	173	77.5	0.32	0.303
3	7	1	18	255	165	165	72.8	0.334	0.308
3	7	2	46	255	191	191	91	0.295	0.294
3	7	1	20	255	208	208	101	0.278	0.287
3	7	2	23	255	175	175	78	0.316	0.3
3	7	1	74	255	173	173	41	0.331	0.301
3	7	1	30	255	146	146	32.4	0.389	0.32
3	7	1	18	255	161	161	37.1	0.357	0.309
3	7	2	13	255	185	185	46.2	0.312	0.294
3	7	1	16	255	205	205	45.3	0.286	0.28
3	7	2	12	255	198	198	42.6	0.295	0.284
3	7	2	25	255	162	162	30.5	0.358	0.306
3	7	2	48	255	175	175	34.2	0.332	0.297
3	7	2	71	255	176	176	34.5	0.33	0.296
3	7	2	67	255	172	172	33.4	0.337	0.299
3	7	2	19	255	165	165	31.4	0.352	0.303
3	7	2	63	255	195	195	40.8	0.299	0.286
3	7	1	42	255	164	164	72	0.335	0.308
3	7	1	22	255	165	165	72.5	0.334	0.307
3	7	1	19	255	165	165	72.6	0.334	0.308
3	7	1	26	255	186	186	85.7	0.301	0.294
3	7	1	20	255	170	170	75.6	0.325	0.303
3	8	2	18	255	211	211	57.9	0.277	0.282
3	8	2	53	255	187	187	47.1	0.309	0.294
3	8	2	6	255	230	230	68	0.259	0.274
3	8	1	16	255	195	195	50.8	0.298	0.289
3	8	1	9	255	215	215	60.6	0.274	0.279
3	8	1	8	255	245	245	77.8	0.247	0.27
3	8	2	8	255	205	205	44.8	0.285	0.28
3	8	2	21	255	184	184	37.3	0.316	0.291
3	8	1	23	255	216	216	50.3	0.274	0.276
3	8	2	37	255	184	184	37.4	0.316	0.291
3	8	1	36	255	185	185	37.5	0.314	0.29
3	8	2	11	255	217	217	49.6	0.272	0.275
3	8	2	95	255	231	231	56.8	0.259	0.27
3	8	1	17	255	190	190	90.5	0.295	0.292

Color	Seq	Hyst	Time	R	G	B	Y	x	y
3	8	1	9	255	237	237	130	0.251	0.278
3	8	2	32	255	206	206	104	0.277	0.287
3	8	1	18	255	190	190	92.7	0.295	0.294
3	8	2	19	255	207	207	106	0.276	0.287
3	8	1	29	255	227	227	119	0.259	0.28
3	8	2	35	255	195	195	94.1	0.29	0.291
3	8	1	41	255	193	193	49.5	0.299	0.29
3	8	1	46	255	172	172	41.2	0.334	0.302
3	8	1	18	255	184	184	45.7	0.314	0.295
3	8	2	15	255	205	205	55.4	0.285	0.284
3	8	1	18	255	225	225	54.1	0.263	0.272
3	8	2	15	255	223	223	53	0.266	0.273
3	8	2	28	255	183	183	37.1	0.318	0.292
3	8	2	29	255	200	200	43.3	0.293	0.282
3	8	2	30	255	202	202	43.8	0.29	0.281
3	8	2	42	255	205	205	44.9	0.286	0.28
3	8	2	18	255	194	194	40.9	0.301	0.286
3	8	2	49	255	214	214	49.1	0.276	0.277
3	8	1	40	255	195	195	96.2	0.289	0.292
3	8	1	23	255	180	180	84.6	0.308	0.298
3	8	1	20	255	186	186	89.3	0.3	0.296
3	8	1	27	255	216	216	111	0.268	0.283
3	8	1	54	255	205	205	102	0.279	0.288
3	9	2	0	255	255	255	70	0.237	0.266
3	9	2	0	255	255	255	68.2	0.238	0.266
3	9	2	0	255	255	255	66.6	0.238	0.267
3	9	1	0	255	255	255	69.7	0.239	0.266
3	9	1	0	255	255	255	69.6	0.239	0.266
3	9	1	0	255	255	255	69.2	0.239	0.265
3	9	2	0	255	255	255	57.2	0.238	0.261
3	9	2	0	255	255	255	56.5	0.238	0.26
3	9	1	0	255	255	255	57.3	0.238	0.262
3	9	2	0	255	255	255	58.6	0.24	0.259
3	9	1	0	255	255	255	57.6	0.238	0.261
3	9	2	0	255	255	255	56.7	0.238	0.261
3	9	2	0	255	255	255	56.6	0.238	0.261
3	9	1	0	255	255	255	113	0.237	0.269
3	9	1	0	255	255	255	119	0.237	0.271
3	9	2	0	255	255	255	122	0.237	0.271
3	9	1	0	255	255	255	123	0.237	0.271
3	9	2	0	255	255	255	123	0.236	0.272
3	9	1	0	255	255	255	114	0.239	0.269
3	9	2	0	255	255	255	120	0.238	0.27
3	9	1	0	255	255	255	69.1	0.237	0.266
3	9	1	0	255	255	255	68.8	0.238	0.265
3	9	1	0	255	255	255	68.9	0.238	0.267
3	9	2	0	255	255	255	69.7	0.239	0.265
3	9	1	0	255	255	255	57.2	0.238	0.261

Color	Seq	Hyst	Time	R	G	B	Y	x	y
3	9	2	0	255	255	255	56.5	0.239	0.26
3	9	2	0	255	255	255	57.3	0.238	0.261
3	9	2	0	255	255	255	56.9	0.238	0.261
3	9	2	0	255	255	255	57	0.238	0.262
3	9	2	0	255	255	255	57.2	0.239	0.261
3	9	2	0	255	255	255	57.2	0.239	0.261
3	9	2	0	255	255	255	59.4	0.239	0.259
3	9	1	0	255	255	255	121	0.237	0.271
3	9	1	0	255	255	255	123	0.237	0.271
3	9	1	0	255	255	255	122	0.236	0.271
3	9	1	0	255	255	255	118	0.238	0.269
3	9	1	0	255	255	255	121	0.238	0.27

APPENDIX B: Programs

```
          call value(v(j,1),v(j,2),v(j,3))
          call prmfil(1)
          call recrel(75,75)
          call movabs(-37,-37)
          call m:clock(time1,inter)
          if (j.eq.1) v(j,colorseq)=0
          if (j.eq.3) v(j,colorseq)=0
          if (j.eq.5) v(j,colorseq)=0
          if (j.eq.7) v(j,colorseq)=0
          if (j.eq.2) v(j,colorseq)=0
          if (j.eq.4) v(j,colorseq)=0
          if (j.eq.6) v(j,colorseq)=0
 10       continue
          if(v(j,colorseq).gt.255)v(j,colorseq)=255
          if(v(j,colorseq).lt.0)v(j,colorseq)=0
           if (colorseq.eq.2.or.colorseq.eq.4) then
            colorseq=4
             v(j,3)=v(j,colorseq)
             v(j,1)=v(j,colorseq)
             v(j,2)=255
           else if(colorseq.eq.1.or.colorseq.eq.3) then
           v(j,2)=v(j,colorseq)
           end if
          call value(v(j,1),v(j,2),v(j,3))
          call prmfil(1)
C         write (6,*) j,colorseq,v(j,colorseq),v(j,1)
          call recrel(75,75)
          call flush
          call READBU(1,1,but1,x,y)
          if (but1.eq.3) go to 30
          k=but1
          select case k
            case 12;m=-5
            case 13;m=-1
            case 14;m=1
            case 15;m=5
            case default
            m=0
          end select
          v(j,colorseq)=v(j,colorseq)+m
          go to 10
 30       continue
          call m:clock(time2,inter)
          time=time2-time1
C         write (6,*) time
          call emptyp
          defined(user(j))=v(j,colorseq)
          write (4,67) i,user(j),v(j,1),v(j,2),v(j,3),time
 67       format(6(i3,2x))
 11     continue
      enddo
      call quit
      close(4)
      stop
      end
      SUBROUTINE READBU (WAIT, CFLAG, BUTTON, X, Y)
C
```

```
C COPYRIGHT (C) 1982, RASTER TECHNOLOGIES, INC.
C
C PACKAGE NAME ............. MODEL ONE GRAPHICS LIBRARY
C
C CLASS .................... VARIANT, I/O
C CPU & OPERATING SYSTEM .. Gould-32 and MPX-32
C I/O TYPE(S) .............. PARALLEL AND SERIAL
C
      INTEGER*2 WAIT,BUTTON,X,Y,CFLAG
C
C   READBU RETURNS THE NUMBER OF A BUTTON PRESSED, AND THE POSITION
C   OF EITHER THE JOYSTICK (CFLAG=0) OR THE DIGITIZER (CFLAG=1)
C   AT THE TIME IT WAS PRESSED.
C
C   PARAMETER:  WAIT - A VALUE OF ONE INDICATES THAT THE MODEL ONE
C                      SHOULD WAIT UNTIL A BUTTON HAS BEEN PRESSED,
C                      UNLESS A BUTTON HAS ALREADY BEEN PRESSED.
C                      A VALUE OF ZERO INDICATES THAT THE MODEL ONE
C                      SHOULD RETURN A ZERO FOR 'BUTTON' IF NONE
C                      HAS BEEN PRESSED.
C
C             BUTTON - THE NUMBER OF THE BUTTON PRESSED (UNLESS
C                      'WAIT' IS ZERO AND NO BUTTON WAS PRESSED).
C
C                X,Y - DIGITIZER COORDINATES AT THE TIME THE BUTTON
C                      WAS PRESSED. (UNDEFINED IF NO BUTTON WAS PRESSE
C
C
C            PROGRAM AUTHOR:  JAY TORBORG
C                     DATE:  4/9/82
C
C MODIFIED:
C
C 18-APR-82 J.M.ESTERLY -- UPDATED /RASTEK/
C 18-APR-82 JME -- ADDED ATTACH GIO AND /RSX/
C 21-APR-82 JME -- EMPTY BUFFER AFTER <ACK> ...
C 23-APR-82 JME -- INPUT LOGICAL UNIT NOW 'LUNIN'
C 27-APR-82 JME -- USES EVENT FLAG #1
C 3-MAY-82 JME -- WTQIO INSTEAD OF READ
C 5-MAY-82 JME -- CHECK FOR I/O ERROR
C 17-MAY-82 JME -- ((IOSTAT(1).AND.255).NE.1) IS ERROR
C 20-SEP-82 JME -- CALLS RTREAD INSTEAD OF DOING QIO
C 13-JAN-83 JME -- UPDATED /RASTEK/, /RSX/, ADDED /ERROR/,
C                  DON'T SEND <ACK> IF CONVERSION ERROR
C 17-JAN-83 JME -- CALL SEND1A FOR <ACK>, NOT SEND1
C 26-JAN-83 JME -- JUST RETURN IF OUTPUT IS TO FILE
C 02-MAR-84 Philip Keller  -- Placed common blocks into include file
C 01-AUG-85 Phillip Nunemacher -- Removed common blocks - RASTEK.I,
C                                 RSX.I, ERROR.I to work with ATLAS
C                                 GIS Package.
C
C
C
     INTEGER*1 BUF(16)
     INTEGER*4 IOSTAT(4)
     INTEGER*2 RTREAD
C
```

```
C              PROGRAM EXECUTION BEGINS HERE * * * * * * * *
C
C   CHECK FOR VALID WAIT FLAG
C
      IF (WAIT .NE. 1 .AND. WAIT .NE. 0) GO TO 500
      IF (CFLAG .NE. 1 .AND. CFLAG .NE. 0) GO TO 500
C
C     OUTPUT COMMAND CHARACTERS
C
      CALL SEND1 (154)
      CALL SEND1 (WAIT)
      CALL SEND1 (CFLAG)
      CALL EMPTYB
C
C READBACK ... BBBXXXXXXYYYYYY<CR>
C
      BUTTON = 0
      X = 0
      Y = 0
C
      IE = RTREAD (1,32,ICSTAT,BUF,16)
      IF (IE.NE.0) GO TO 9000
C
C
      BUTTON=(BUF(2)-48)*10+BUF(3)-48
      X=(BUF(5)-48)*10000+(BUF(6)-48)*1000+(BUF(7)-48)*100+(BUF(
     *8)-48)*10+BUF(9)-48
      IF (BUF(4) .EQ. 45) X=-X
      Y=(BUF(11)-48)*10000+(BUF(12)-48)*1000+(BUF(13)-48)*100+(B
     *UF(14)-48)*10+BUF(15)-48
      IF (BUF(10).EQ.45) Y=-Y
C
C ACKNOWLEDGE RECEIPT ...
C
      CALL SEND1 (6)
      GO TO 9999
C
C ERROR ...
C
  500 CALL IERROR ('READBU', 4, )

      GO TO 9999
C
 9000 CALL IERROR ('READBU',28,ICSTAT)
      STOP
C
 9999 RETURN
      END
```

07/24/87 15:20:59 TASK # 13000011 JOE GOULD

```
      program readdat
      character*16 oname,iname
      integer left(7),right(7),user(7),colorseq,defined(9)
      integer*4 out1,v(9,4)
      integer*4 time1,time2,time,inter,a,b,c
      integer*2 x,y,k,q
       data left / 1,5,5,9,1,7,5 /
       data right / 9,1,9,7,3,5,3 /
      call rtinit
      call entgra
      write (6,*) 'input file name '
      read (5,66) iname
66    format(A6)
      write (6,*) 'output file name '
      read (5,66) oname
      open (unit=4,file=iname,blocked=.true.)
      open (unit=8,file=oname,blocked=.true.)
      do colorseq = 1,3
         do j=1,7
           do k=1,3
             v(j,k)=255
           enddo
         enddo
        if (colorseq.eq.1) then
          v(1,1)=0
          v(1,2)=0
          v(1,3)=255
         endif
        if (colorseq.eq.2) then
          v(1,1)=0
          v(1,2)=255
          v(1,3)=0
         endif
        if (colorseq.eq.3) then
          v(1,1)=255
          v(1,2)=0
          v(1,3)=0
         endif
          v(9,1)=255
          v(9,2)=255
          v(9,3)=255
       do 11 q = 1,7
         call val3(175)
         call flood
         call movabs(-37,-150)
         read (4,67) i,j,v(j,1),v(j,2),v(j,3),time
67       format(6(i3,2x))
         call value(v(left(q),1),v(left(q),2),v(left(q),3))
         call prmfil(1)
         call recrel(75,75)
         call movabs(-37,76)
         call value(v(right(q),1),v(right(q),2),v(right(q),3))
         call prmfil(1)
         call recrel(75,75)
         call movabs(-37,-37)
         call value(v(j,1),v(j,2),v(j,3))
         call prmfil(1)
```

```
        call recrel(75,75)
        call flush
        call READBU(1,1,but1,x,y)
        if (but1.eq.3) go to 30
 30     continue
        write (6,*) 'cie a '
        read (5,*) a
        write (6,*) 'cie b '
        read (5,*) b
        write (6,*) 'cie c '
        read (5,*) c
       write (3,68) i,j,v(j,1),v(j,2),v(j,3),time,a,b,c
 68     format(9(i3,2x))
        call emptyb
 11   continue
      enddo
      call quit
      close(4)
      close(5)
      stop
      end
      SUBROUTINE READBU (WAIT, CFLAG, BUTTON, X, Y)
C
C COPYRIGHT (C) 1932, RASTER TECHNOLOGIES, INC.
C
C PACKAGE NAME ............. MODEL ONE GRAPHICS LIBRARY
C
C CLASS ..................... VARIANT, I/O
C CPU & OPERATING SYSTEM .. Gould-32 and MPX-32
C I/O TYPE(S) .............. PARALLEL AND SERIAL
C
      INTEGER*2 WAIT,BUTTON,X,Y,CFLAG
C
C   READBU RETURNS THE NUMBER OF A BUTTON PRESSED, AND THE POSITION
C   OF EITHER THE JOYSTICK (CFLAG=0) OR THE DIGITIZER (CFLAG=1)
C   AT THE TIME IT WAS PRESSED.
C
C   PARAMETER:  WAIT - A VALUE OF ONE INDICATES THAT THE MODEL ONE
C                      SHOULD WAIT UNTIL A BUTTON HAS BEEN PRESSED,
C                      UNLESS A BUTTON HAS ALREADY BEEN PRESSED.
C                      A VALUE OF ZERO INDICATES THAT THE MODEL ONE
C                      SHOULD RETURN A ZERO FOR 'BUTTON' IF NONE
C                      HAS BEEN PRESSED.
C
C             BUTTON - THE NUMBER OF THE BUTTON PRESSED (UNLESS
C                      'WAIT' IS ZERO AND NO BUTTON WAS PRESSED).
C
C                X,Y - DIGITIZER COORDINATES AT THE TIME THE BUTTON
C                      WAS PRESSED. (UNDEFINED IF NO BUTTON WAS PRESSE
C
C
C         PROGRAM AUTHOR:  JAY TORBORG
C                   DATE:  4/9/82
C
C
C MODIFIED:
C
C 18-APR-82 J.M.ESTERLY -- UPDATED /RASTEK/
```

```
      CALL SEND1 (6)
      GO TO 9999
C
C ERROR ...
C
  500 CALL IERROR ('READBU', 4, )

      GO TO 9999
C
 9000 CALL IERROR ('READBU',28,IOSTAT)
      STOP
C
 9999 RETURN
      END
```

```
C 18-APR-82 JME -- ADDED ATTACH QIO AND /RSX/
C 21-APR-82 JME -- EMPTY BUFFER AFTER <ACK> ...
C 23-APR-82 JME -- INPUT LOGICAL UNIT NOW 'LUNIN'
C 27-APR-82 JME -- USES EVENT FLAG #1
C 3-MAY-82 JME -- WTQIO INSTEAD OF READ
C 5-MAY-82 JME -- CHECK FOR I/O ERROR
C 17-MAY-82 JME -- ((IOSTAT(1).AND.255).NE.1) IS ERROR
C 20-SEP-82 JME -- CALLS RTREAD INSTEAD OF DOING QIO
C 13-JAN-83 JME -- UPDATED /RASTEK/, /RSX/, ADDED /ERROR/,
C                  DON'T SEND <ACK> IF CONVERSION ERROR
C 17-JAN-83 JME -- CALL SEND1A FOR <ACK>, NOT SEND1
C 26-JAN-83 JME -- JUST RETURN IF OUTPUT IS TO FILE
C 02-MAR-84 Philip Keller  -- Placed common blocks into include file
C 01-AUG-85 Phillip Nunemacher -- Removed common blocks - RASTEK.I,
C                                 RSX.I, ERROR.I to work with ATLAS
C                                 GIS Package.
C
C
C
      INTEGER*1 BUF(16)
      INTEGER*4 IOSTAT(4)
      INTEGER*2 RTREAD
C
C             PROGRAM EXECUTION BEGINS HERE * * * * * * * * *
C
C   CHECK FOR VALID WAIT FLAG
C
      IF (WAIT .NE. 1 .AND. WAIT .NE. 0) GO TO 500
      IF (CFLAG .NE. 1 .AND. CFLAG .NE. 0) GO TO 500
C
C     OUTPUT COMMAND CHARACTERS
C
      CALL SEND1 (154)
      CALL SEND1 (WAIT)
      CALL SEND1 (CFLAG)
      CALL EMPTYB
C
C READBACK ... BBBXXXXXXYYYYYY<CR>
C
      BUTTON = 0
      X = 0
      Y = 0
C
      IE = RTREAD (1,32,IOSTAT,BUF,16)
      IF (IE.NE.0) GO TO 9000
C
C
      BUTTON=(BUF(2)-48)*10+BUF(3)-48
      X=(BUF(5)-48)*10000+(BUF(6)-48)*1000+(BUF(7)-48)*100+(BUF(
     *8)-48)*10+BUF(9)-48
      IF (BUF(4) .EQ. 45) X=-X
      Y=(BUF(11)-48)*10000+(BUF(12)-48)*1000+(BUF(13)-48)*100+(B
     *UF(14)-48)*10+BUF(15)-48
      IF (BUF(10).EQ.45) Y=-Y
C
```

```
      program ptest
      character*16 name,fname
      integer left(7),right(7),user(7),colorseq,defined(9)
      integer*4 but1,v(7,4)
      integer*4 time1,time2,time,inter
      integer*2 x,y,k
      data left / 1,5,5,9,1,7,5 /
      data user / 5,3,7,3,2,6,4 /
      data right / 9,1,9,7,3,5,3 /
      inter = 12
      call rtinit
      call entgra
      write (6,*) 'input file name '
      read (5,66) fname
   66 format(A6)
      open (unit=4,file=fname,blocked=.true.)
C     write (6,*) 'time '
C     write (6,*) 'test subject '
      do i = 1,3
C       write (6,*) '1=cyan  2=magenta  3=yellow  '
C       write (6,*) 'define color test '
C       read (5,7) colorseq
C  7    FORMAT(I4)
        colorseq=i
        defined(1) = 0
        defined(9) = 255
        do j = 1,7
          do k = 1,3
            v(j,k) = 255
          enddo
        enddo
        do 11 j = 1,7
          call val8(175)
          call flood
          call movabs(-37,-150)
          v(j,colorseq)=defined(left(j))
           if (colorseq.eq.2.or.colorseq.eq.4) then
            colorseq=4
             v(j,3)=v(j,colorseq)
             v(j,1)=v(j,colorseq)
             v(j,2)=255
           else if(colorseq.eq.1.or.colorseq.eq.3) then
           v(j,2)=v(j,colorseq)
           end if
          call value(v(j,1),v(j,2),v(j,3))
          call prmfil(1)
          call recrel(75,75)
          call movabs(-37,76)
          v(j,colorsaq)=defined(right(j))
           if (colorseq.eq.2.or.colorseq.eq.4) then
            colorseq=4
             v(j,3)=v(j,colorseq)
             v(j,1)=v(j,colorseq)
             v(j,2)=255
           else if(colorseq.eq.1.or.colorseq.eq.3) then
           v(j,2)=v(j,colorsaq)
           end if
```