

Teaching Considerate Colour design for people with colour-defective vision

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Abstract:

Graphic designers with normal colour vision often make the mistake of creating works that cannot be interpreted correctly by people with colour defective vision (a condition often called “colour blindness”). Though most designers and the teachers who instruct them in design are aware, the selection of colour in design must be both an aesthetic and a practical process. The practical part must include consideration of the small but significant percentage of people who do not see colour normally. This essay describes practical techniques for choosing colour palettes that will deliver successful designs that are also effective for colour-defective viewers.

1. Background

Human vision is a complex topic, and a subject on which a tremendous amount has been written. There are two general fields of research on human vision: the study and understanding of how the human eye works – chemically, physiologically, and biologically, and the observational study of how humans see.

Within the field of observational study is the topic of colour-defective vision. Researchers have developed an accurate understanding of the numerous genetically-caused defects found in human vision, and have mapped both normal human colour perception and a range of colour defects. (Kalmus, 1965)

In general, there are six types of colour-defective vision: red-green, green-red and blue. One additional type is achromatopsia, where there is no colour sensation at all. The six primary defects are described with different word suffixes: opia and omaly. Those defects ending with opia – deuteranopia, protanopia and tritanopia – describe people whose eyes lack colour sensors (cones) of a specific sensitivity. Those defects ending with omaly – deuteranomaly, protanomaly and tritanomaly – describe people with colour sensors, but whose sensors are defective. These defective sensors vary significantly from a very

small degree of insensitivity to total insensitivity. This explains how some people have a mild form of colour-defective vision while others have severe colour-defective vision. (Jenny, Kelso, 2007)

People without any colour defects are called normal by all of the researchers cited in this study. Normal describes approximately 90 percent of the human population.

Color Vision	Cones	Percentage Affected
Normal	Normal	≈ 90%
Deuteranopia	Green absent	1% Males; <1.0% Females
Deuteranomaly	Green defective	6.0% Males; 0.4% Females
Protanopia	Red absent	1.0% Males; <1.0% Females
Protanomaly	Red defective	1.0 % Males; 0.01% Females
Tritanopia	Blue absent	<1.0% Males and Females
Tritanomaly	Blue defective	0.01% Male; 0.01% Females
Achromatopsia	No color sensitivity	<0.001% Male; <0.001% Female

Figure 1: Chart of Colour Defects
This chart describes the seven colour defects in human vision. All of these are caused by genetic mutation. For this essay, only the two marked in tan are considered because they represent the largest percentage of the population affected by genetic colour defects. (From Kalloniatis et al. “The Perception of Colour” 2007 and Kolb et al., 2007)

These seven variations are called as a group colour-defective vision. People with these visual characteristics are referred to as being colour-defective, while those whose vision is normal are called normal. People with either deuteranopia or deuteranomaly are together referred to as deuteranopic in this essay.

This essay addresses only the most common of the colour defective anomalies: deuteranopia and deuteranomaly. Colours selected using these techniques are also effective for the second-most common colour defective condition: protanopia. These techniques may be effective for tritanopic viewers, but that is not the focus of this study.

2. What deuteranopic people see

People with this form of red-green colour-defective vision see colours in the red-green spectrum as a tonally-varied arc of greenish colours. For these people, there is almost no difference between the extremes of red and green, and there is no red, orange or magenta in their spectrum of colour vision.



Figure 2: The spectrum of colours seen by a person with normal vision, left, and the colours visible to a person with deuteranopic vision, right. Note that the range of hues is limited to yellow-green on the lower-left to gray-green on the top-center. This creates a severe limitation of the colours that can be used for graphic design when catering to people with deuteranopic colour-defective vision. (Illustrations by the author)

The challenge for educators in the graphic arts is to help students understand the importance of designing with colours that can be seen by people whose vision is abnormal. This is especially true when the colours used in a design convey the information value of the product.

An excellent example of this is a public transit map showing the routes taken by buses combined with bus stops. A person with normal colour vision will be able to differentiate the routes easily. But a person with deuteranopic colour vision may not see a difference between the colours, and thus be unable to differentiate the routes and stops. (Jenny, Kelso, 2007)

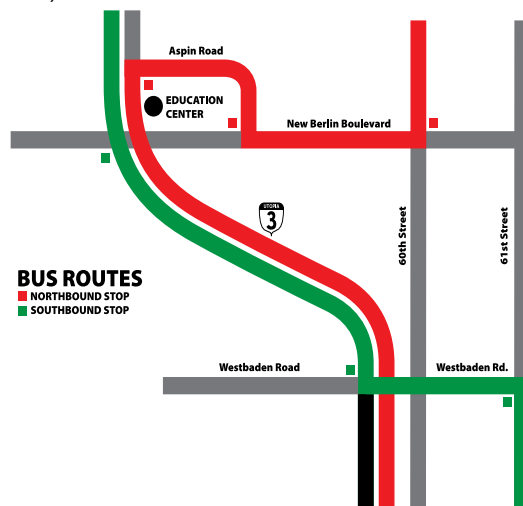


Figure 3: The map above shows two routes of a public transportation system. To a person with normal vision the red and green route lines are clearly visible and easy to differentiate. (Illustration by the author, 2016)



Figure 4: The same transportation map as seen by a person with deuteranopic vision. About six percent of males, and a smaller percentage of female viewers cannot differentiate the two bus routes. (Illustration by the author, 2016)

The transit maps shown in figures 3 and 4 illustrate the problem. How can we design the same transportation map using colours that do not confuse more than six percent of the population?

To become more effective in teaching graphic design, and colour design specifically, it is important for teachers to explain and demonstrate how people with colour-defective vision see colours. There are three effective tools for demonstrating colour vision deficiencies on a computer display.



Figure 5: This version of the same map uses colours that can be seen effectively by people with normal colour vision, and by those with deuteranopic vision. Its colours were selected with consideration for the red-green weakness of the deuteranopic viewer (see also Figures 9 and 10). (Illustration by the author, 2016)

The first two are Adobe Photoshop and Adobe Illustrator, both of which feature a tool for previewing colours for the two most common types of colour-defective vision. The third is a stand-alone application called Colour Oracle. All are helpful in visualizing the challenge of design for colour-defective viewers (See “Simulating how colour is seen by colour-defective viewers” later in this essay).

More importantly, it is critically important for educators to understand the underlying concepts of colour-defective vision, and to be able to address these concepts in the classroom. Many people do not realize the challenges faced by those with colour-defective vision. To be able to simulate the view that these people experience when looking at print and electronic graphics is a valuable tool for the teacher of graphic design. It helps design students to understand the impact of their colour choices on the viewer, and it creates an environment where designers are considerate of their fellow man who cannot always see colour the way that people with normal vision see colour.

3. Does designing for the colour-defective ruin graphic design?

Designers can be offended by the idea that they should (or must) modify their colour palettes to accommodate a small percentage of the population. Occasionally one hears a complaint that designing with colour in this way is a form of unnecessary political correctness. However, this accommodation is not necessary for every product. However, when colour itself is the element of communication – as is the case with maps and infographics – then the colours chosen for the design must be visible to the entire population of viewers. Colour used in other ways – such as accents, backgrounds, etc. – does not need to be chosen with such care.

4. Confusion lines

In his essay *Research on Normal and Defective Colour Vision* (1946), W.D. Wright illustrates an arbitrary number of 27 confusion lines superimposed on a Chromaticity chart. These lines show how a person with deuteranopic colour vision will confuse a series of colours that cross the Chromaticity chart laterally from the green-blue axis to the blue-red axis. Researchers have accepted and expanded the concepts of these confusion lines in many research papers since. (Pirenne, 1967)

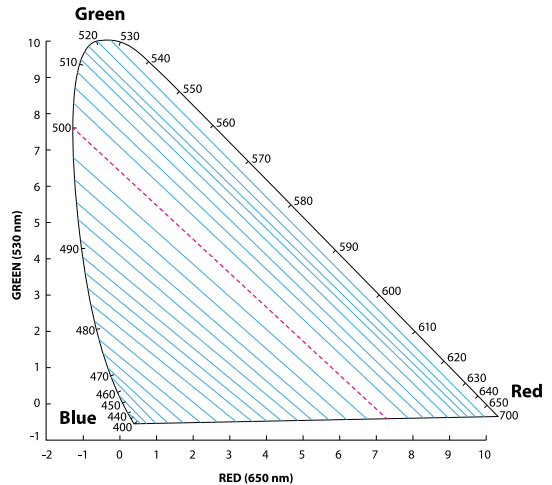


Figure 6: Deuteranopic confusion lines, as described by W.D. Wright in his 1946 essay on defective colour vision. Choosing two colours along any of these lines will result in confusion in the red-green colour-defective viewer. The red line in the middle bisects the Chromaticity chart, which is analogous to the delineation of Colour Vectors as described in this essay. (from Wright, 1946, simplified)

5. The concept of Colour Vectors

Simplifying the process of teaching the concept of confusion lines (without using the Chromaticity chart) involves shifting to the more common, and more easily understood colour wheel. By plotting colours on a colour wheel, designers can easily predict the colours that are difficult to differentiate for colour-defective viewers. I call these plotted areas Colour Vectors. By superimposing vector areas on top of a colour wheel, it is easy to teach students of graphic design how to select colours that will be visible to those with defective vision.

This technique allows the designer to draw a vector around approximately one-third of the colours in the visible spectrum, and declare the entire area to be an area of greatest concern for graphic design.

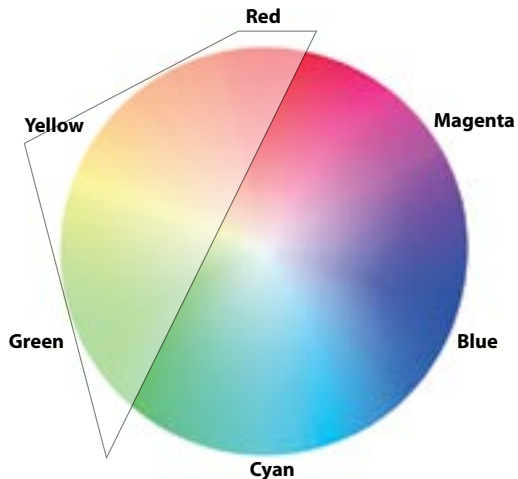


Figure 7: This Colour Vector indicates the area of greatest concern for deuteranopic viewers. Choosing any two colours from within this range is problematic because these viewers cannot discriminate between the two colours. By modifying the selection of colour pairs, it is possible to choose colours that are more easily differentiated. (Illustration by the author, 2016)

For deuteranopic viewers, these vectors converge approximately on red. The width of the other end of the vector is quite wide, encompassing all of the yellows, most of the greens, and some of the colours that exist between cyan and green at the bottom-left of the colour wheel.

Considering how few colours are present in the deuteranopic hemisphere of the colour wheel (the approximate upper-left third), the selection of a second, contrasting colour requires that the selection be made from the opposite hemisphere of the colour wheel. Colours in the cyan-blue range will usually create a difference that is easily distinguished by a colour-defective viewer.

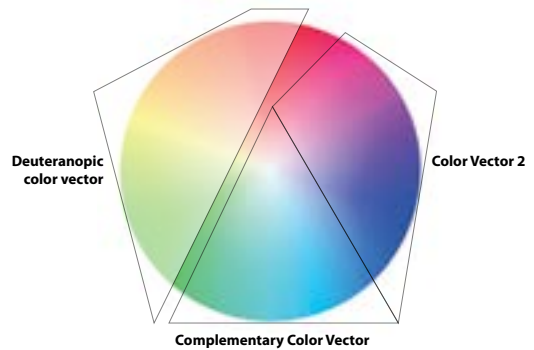


Figure 8: Colour Vectors for Considerate Colour design. By selecting one colour from the Deuteranopic colour vector (upper-left), and additional colours from Colour Vector 2 or the Complementary Colour Vector, a designer has a better chance of choosing colours that can be seen as “different” by deuteranopic viewers. A space is left between the three Vectors to enhance the differences between selected colours. (Illustration by the author, 2016)

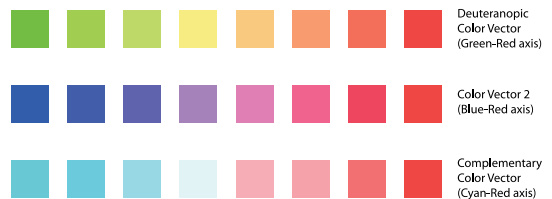


Figure 9: Three sets of eight colours chosen from these vectors on the colour wheel. The top row is chosen from the Deuteranopic Colour Vector. The middle row is selected from the Colour Vector 2. The bottom row is taken from the Complementary Colour Vector. All vectors converge on the same red colour. (Illustration by the author, 2016)



Figure 10: The same colour patches as seen by a deuteranopic viewer. As can be seen here, the selection of two colours from the first vector is problematic because the colours all appear to have the same “chroma” (colour) though there is some variation of value. The middle selection has adequate chroma differences, and two colours selected from this row would work well together. In the last row there is greater value difference (note the pale gray-blue in the fourth position), and a similar chroma difference. The middle and bottom rows would yield colours that will be seen as “different” by a colour-defective individual. (Illustration by the author, 2016)

Teachers who understand how these vectors can be applied to colour selection can assist their students in the selection of colours that are both attractive to normal viewers, and effective for people with defective colour vision.

6. The practical application of these concepts

Though using the colour wheel is an effective tool for explaining the concept of Colour Vectors to design students, it is not practical. Curiously, no popular software application presents the colour wheel as a selection tool. The Adobe Creative Cloud applications allow the user to select colours from several different palettes: HSB, RGB and CMYK in Illustrator and InDesign, with a CIE Lab colour picker added in Adobe Photoshop. (Hexadecimal values are a different method for describing RGB colours, not a different colour system.)

Of all these selection palettes, only the CIE Lab colour picker in Photoshop is useful for the selection of colours in a manner similar to that described here. Instead of choosing colours as imaginary vectors on top of a colour wheel, one can select colours from the top half or the bottom half of the colour picker that is present when the L channel is selected in the Colour Picker in Photoshop (see Figures 11 and 12).



Figure 11: The Colour Picker in Adobe Photoshop presents the only location for choosing colours that are similar to using the Colour Vectors described in this essay. By choosing the L channel (shown here), the colours are presented in a way that effective colours can be selected from the upper-half and the lower-half of this palette. Such selections are essentially the same as opposing hemispheres on the colour wheel. Unfortunately, this Lab colour picker is not available in Adobe InDesign or Adobe Illustrator

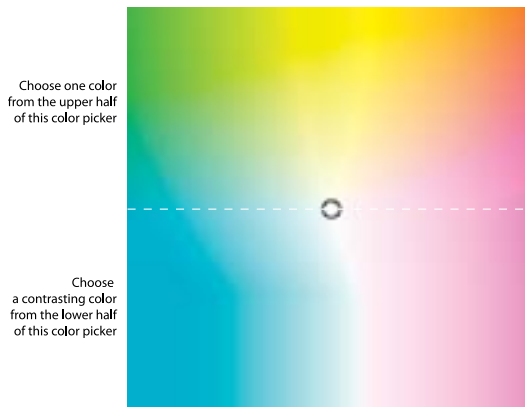


Figure 12: Choosing colours from the upper and lower halves of the CIE Lab colour picker in Adobe Photoshop. (Illustration by the author, 2016)

Fortunately, there is a simple method for exporting palettes of colours that can be added to documents in the other two Adobe Creative Cloud applications. Adobe has created a menu in each application for saving swatches “for Exchange” and also for loading these swatch files (called .ase files). Once a palette of colours has been created in Photoshop, that palette can be exported as an .ase file, and then loaded into InDesign or Illustrator. Once loaded into those applications, the swatches behave just as other colour swatches do.

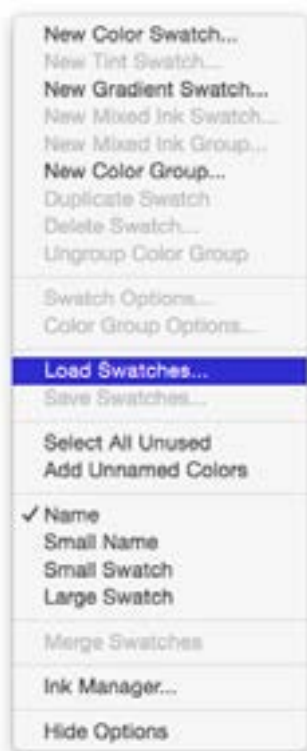


Figure 13: Loading an Adobe colour swatches file (.ase) into Adobe InDesign. By choosing this fly-out menu from the Colour Swatches menu in Adobe InDesign (or the similar menu in Illustrator), it is possible to pass colour swatches from Photoshop to the other Creative Cloud applications.

7. Simulating how colour is seen by colour-defective viewers with computer software

Graphic arts teachers can teach their students how to simulate colour-defective vision in Adobe Photoshop and Illustrator (this tool is not available in InDesign). Using either application, and choosing from the View menu, one can choose to simulate the two most common types of colour-defective vision (Adobe calls the phenomenon “Colour-blindness”).



Figure 14: Adobe Illustrator’s menu for simulating the two common types of colour-defective vision. The menu in Adobe Photoshop is similar

A more effective tool for simulating colour-defective vision is a free application called Colour Oracle, written by Swiss cartographer Dr. Bernhard Jenny. When activated, Colour Oracle turns the entire computer display into a simulation of colour-defective vision. It will demonstrate the three types of colour vision, and it will create a screen capture to save an example of the effect of colour-defective vision. Compared to the techniques described above (only available in Adobe Illustrator and Photoshop), this is much easier, and it works for any computer running any application.

Teachers who want their students to understand the effect of colour-defective vision can demonstrate these tools to their students, and have their students make variations of their designs to study and preview how colours interact with each other in the varied circumstances possible in Colour Oracle.

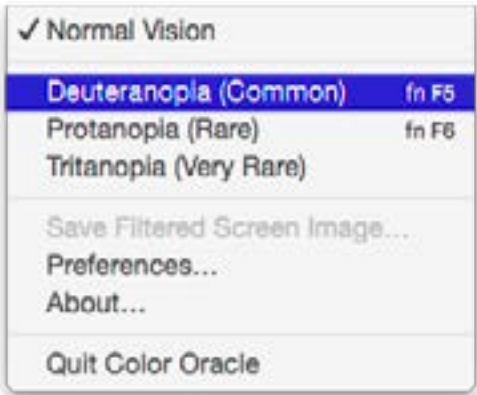


Figure 15: The Colour Oracle menu. Selecting from the three types of colour-defective vision will turn your entire computer display into the colours as seen by a person with that vision anomaly.

8. Conclusion

By applying the concepts of Colour Vectors to teach Considerate Colour design, a graphic arts instructor can contribute to the education of thoughtful, skilful students. These students can then prepare artwork and colourful information graphics that are both attractive and functional. Their colour choices will help the small percentage of the population with colour-defective vision to see and understand information based on its colour as well as its content.

Note on software versions

All references to Adobe software products refer to the 2015 Creative Cloud versions, though these tools and palettes may appear in previous versions of the software.

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