Introduction

When it comes to digital color prepress imaging, Adobe’s Photoshop is used just about everywhere. There are technical conferences and video tape series just on how to use Photoshop effectively as a prepress production tool. For graphic arts teachers and trainers, it makes sense to use Photoshop as a tool to teach both the production techniques of pixel/color editing and the concepts of tone and color reproduction.

This article documents a series of tone and color demonstrations regarding color theory with the use of Photoshop. All color illustrations in this article are reproduced in black-and-white; the reader is encouraged to access a PDF version of this paper in color from the author’s www site at http://www.rit.edu/~rycppr/.

This document begins by explaining how to create a spectrum and practical uses of the spectrum are demonstrated. The next section explains how gray scales are created and may be used to study tone reproduction. The article then shows how to create the additive color mixing demonstration. This part of the demonstration conveys the concept of color separation and how color television works. Lastly there is a discussion of subtractive color mixing, and an explanation of process color printing, gray balance, and moiré pattern.

Photoshop Preparation

This article is written based on the author’s experiences in using version 3.0.4 of Adobe’s Photoshop running on a Macintosh computer. It assumes that the reader knows the basics of Mac operations and Photoshop. To start out, set your color monitor to thousands or millions colors via Mac’s Control Panels. Also, check the box, ‘Color channels in color’ in Photoshop’s Preferences / General settings / Display dialog box.

Spectrum Demonstration

Normally, we need a prism and a slide projector in a darkened room to show that white light is composed of energies of different wavelengths. To do this with Photoshop, follow the steps outlined below.

1. Open a new file and set the image size, e.g., 5 in. wide by 4 in. long. Choose RGB mode at 72 dpi resolution (figure 1a) with a black background. The black background is to simulate the darken room where there is no energy to begin with.

2. Set the foreground color to solid blue (255 digital values), and the background color to solid red color (figure 1b).

3. Use the gradient tool to draw a line from left to right with the tool specified as shown in figure 1c. Pay atten-
tion to the style and midpoint settings. The result is a spectrum in the correct orientation (figure 1d).

![Gradient Tool Options](image1.png)

Figure 1c. Gradient tool options.

Figure 1d. The visible spectrum.

4. There are two places the spectrum may be improved. First is the alignment between the wavelength and the color it represents. For example, the wavelength of 580 nm should coincide with the yellow. This can be achieved by experimenting with the starting and ending points when using the gradient tool. The second improvement is the darkening of either side of the spectrum. To accomplish this, use layers and the gradient tool.

a) Go to Windows / Palettes and Show Layers. Add a new layer and name the layer ‘spectrum left’. When naming the layer, set opacity to ‘100’ and mode to ‘Darken’.

b) Set the foreground color to solid black (255 digital values), and the background color to white.

c) Use the gradient tool to draw a line from far left to one-third of the width and you will see the darken effect on the left-hand-side of the spectrum. In the same manner, darkening the right-hand-side of the spectrum.

5. Once you are satisfied with the appearance of the spectrum, you should flatten all layers and save it as a PICT file.

The primary use of the spectrum is to show that white light is made up of a range of wavelengths as we would see in a rainbow. Broadly speaking, a white light is made up of a red portion (long wavelength), a green portion (medium wavelength), and a blue portion (short wavelength) of the spectrum. The spectrum may be used as the background for a number of graphs relating to wavelength data. For example, we can show how a process ink (cyan, magenta, or yellow ink) absorbs and reflects certain portion of the spectrum with its spectral reflectance curves (figure 1e, 1f, and 1g).

![Spectral Reflectance Curves](image2.png)

Figure 1e. Spectral reflectance curve of a cyan ink.

Figure 1f. Spectral reflectance curve of the magenta ink.

Figure 1g. Spectral reflectance curve of the yellow ink.

**Gray Scale Demonstration**

Gray scale is a systematic sampling of various tones in an image. By including a gray scale with an original in the reproduction process, we can study the tonal relationship between the original and its reproduction. To create a digital gray scale in Photoshop, follow the steps listed below:

1. Open a new file and set the image size, e.g., 4 in. wide by 1 in. long. Choose gray scale mode and set the resolution (dpi) at twice the screen rulings with a white background.

2. Set the foreground color and the background color to
its default black and white, and then switch the two so that foreground is white.

3. Use the gradient tool to draw a line from left to right. The result is a gradation from white to black (figure 2, top).

4. Use Image / Map / Posterize to separate the gradation to, say, 10 steps. Now, what we have is a 10-step gray scale (figure 2, middle).

The following steps describe a simple approach to convert the appearance of a continuous-tone gray scale to halftone.

1. Change the gray scale mode to bit map mode.
2. Set output resolution (dpi) and halftone screen rulings (lpi). In order to achieve a very coarse halftone (figure 2, bottom), set the resolution to 72 dpi and halftone screen rulings to 9 lpi.

![Figure 2.](image)

Figure 2. (top) a gradation from black to white; (middle) a 10-step gray scale; (bottom) a coarse halftone scale.

Additive Color Mixing Demonstration

To physically demonstrate the principles of additive color mixing, we need three slide projectors stacked up in a rack to separately project a red light, a green light, and a blue light in a darkened room. By manipulating the three lights, we can show how lights behave additively with respect to human color perception. To demonstrate this with Photoshop, the ‘Layers’ feature is used. The following is what you need to do:

1. Open a new file and set the dimension to 5 in. x 5 in. Choose RGB mode at 72 dpi as before. Fill the entire image area black.
2. Go to Windows / Palettes and Show Layers. Add a new layer and named the layer ‘Red light.’ When naming the layer, set opacity to ‘100’ and mode to ‘Lighten’ (figure 3a). Now the original file is known as background.
3. By highlighting the ‘Red light’ layer (figure 3b), draw a circle with 1” diameter and fill the circle with a bright red color (255 digital count).

![Figure 3a.](image)

Figure 3a. Naming a new layer as the red light.

![Figure 3b.](image)

Figure 3b. Draw a circle and fill it with red.

4. Add two more layers in the same manner and name them ‘Green light’ layer and the ‘Blue light’ layer.
5. When a layer is highlighted, you can move the circle around with the move tool. And by turning all 3 layers and the background on, you will see the effect of additive color mixing (figure 3c).

![Figure 3c.](image)

Figure 3c. The additive color mixing principle.

The overlap of red and green lights yields yellow; the overlap of green and blue lights yields a cyan sensation; and the overlap of red and blue lights yields a magenta sensation. Since spectral energies are additive, the overlap of all three lights produces the white sensation.

An important application of the additive color mixing
principle is color separation. The fact that red, green, and blue filters only pass one-third of the spectral energy gives us the ability to separate every pixel in an original into its respective red, green, and blue separation records (figure 3d). To do this, we first open a TIFF/RGB image in Photoshop. By selecting ‘Show Channels’ and clicking the ‘eye’ to turn on or off each channel, we can appreciate the effect of additive color mixing.

The other important application of the additive color mixing principle is additive color reproduction, or how color television works. Examine the face of a color monitor with a loupe. Here, we can see how colors are reproduced with various amounts of red, green, and blue lights very closely interlaced together.

**Subtractive Color Mixing Demonstration**

Process color printing such as magazine ads are examples of subtractive color mixing. But the evidence may not be as effective as an overlay-type color proof, like Color Key, when placed on top of a transparency viewer for demonstration purposes.

Similar procedures used in the additive color mixing demonstration apply when simulating subtractive color mixing with Photoshop. Here, the three layers are named as ‘Cyan ink’, ‘Magenta ink’, and ‘Yellow ink.’ Three exceptions are that:

1. The file should be in CMYK mode;
2. The content should be set to white to represent white paper;
3. The mode of each layer should be set to ‘Darken’.

Figure 4a shows the effect of subtractive color mixing. Notice how red, green, and blue colors are resulted by overlapping two of the three subtractive primaries. In addition, the darkest area (black) is where all three layers meet. Colorants remove energies, giving the meaning of the word, subtractive, in subtractive color mixing.

Figure 4a. The subtractive color mixing principle.

An immediate application of subtractive color mixing is to show how color reproduction can be resulted by printing cyan, magenta, yellow, and black inks on white paper. To do this, we first open a TIFF/RGB image in Photoshop. We then set appropriate UCR, black printer limit, and TAC values in the ‘Separation Setup’ (figure 4b) before mode change to CMYK. By selecting ‘Show Channels’ and clicking the ‘eye’ to turn on or off each channel, we can examine the effect of subtractive color mixing (figure 4c).

Figure 4b. Photoshop separation setup dialog box.

Figure 4c. Color image reproduction by means of mixing the subtractive color primaries, KCMY.
Gray Balance Demonstration

Let’s take the subtractive color mixing concept further and think about how gray balance concept may be demonstrated with Photoshop. To do it,

1. We first prepare a CMYK file with a white background.
2. We can add four layers, i.e., Cyan ink, Magenta ink, Yellow ink and Neutral.
3. We set up two fields, one with neutral only. The other fields are superimposed with C, M, and Y layers (figure 5a).

To demonstrate moiré and rosette pattern in Photoshop, you need two pieces of halftone tints. By overlapping and rotating one halftone film over the other, the moiré effect can be seen. When two halftone screen angles differ by 30 degrees, the moiré pattern becomes least noticeable. This moiré-free pattern is referred as rosette.

To demonstrate moiré and rosette pattern in Photoshop, following these steps:

1. Create a gray scale file with an image size of 2” by 2” at the resolution of 100 dpi. Assign the entire image with a, say, 30% black tint.
2. Through mode change, convert the gray scale to bit map / halftone. It is a good idea to keep the halftone screen rulings very low, e.g., 5 lpi (figure 6b)
3. Through mode change again, convert the bit map image back to gray scale. This makes layer option possible.
4. Add a layer and place various angle indicators, e.g., 0, 15, 45, 75, and 90 degrees, with the line tool.
5. Add another layer and copy the halftone pattern to the layer. Change the opacity to, say 75%, so that there are visual differences between the background halftone and the layer halftone.
6. With the layer halftone activated, use the marquee tool to select an area; go to image / rotate / free rotation. You can click and drag a corner of the box and see the effect of moire or rosette patterns (figure 6c).
7. By converting the gray scale file to the RGB mode; and by adding additional layers and changing halftones into

Figure 5a. CMY adjustable patch and a black tint patch.

Figure 5b. Adjusting the gray with the opacity slider.

Now the challenge is to set the values for C, M, and Y with their respective sliders so that the 3-color overlap matches that of the neutral patch. This demonstration is highly interactive and can be repeated at different black intensities by different students.

Moiré and Rosette Demonstration

In color printing, lighter tones of any color, including grays, are made by combinations of CMYK halftone dots. When arbitrarily overlapping two or more periodic (AM conventional) halftone patterns together, an interference pattern will become evident (figure 6a). This visually annoying and objectionable pattern is called moiré.
CMY colors, you can simulate moiré and rosette patterns in process color (figure 6d).

Figure 6c. (left) moiré pattern; (right) rosette pattern simulated in black-and-white duotone.

Figure 6d. (left) moiré pattern; (right) rosette pattern simulated in CMY layers.

On-screen Documentation

You may find presentation software like Microsoft’s PowerPoint handy in capturing your work for future references. While there are a number of file formats used in digital imaging, PowerPoint only renders PICT images well. Files containing layers must be saved in Photoshop format. To convert the Photoshop file to PICT file, you need to ‘flatten’ the wanted layers before you can save it. In some cases, the file is in CMYK mode, and the PICT file format is not available. Make sure that the CMYK file is converted into RGB mode before you can save it as a PICT file. In addition, a control panel device, called Flash-It, is very useful in capturing a section of the screen and saving it as a PICT file.

Conclusion

Photoshop has become the default image editing software in the graphic arts industry and academic communities. It makes sense to use Photoshop to demonstrate color. Besides, it is fun, and is quite interactive from both a teaching and learning point of view. The author has been teaching color and its reproduction for many years. He relies on many teaching aids such as slides, filters, light sources, and three projectors in a rack to do color demonstrations. While no single teaching aid can perform all the color demonstrations, many of these demonstrations can be created, like virtual reality, with the use of Photoshop.

About the Author

Robert Chung is a faculty member in the School of Printing Management and Sciences, Rochester Institute of Technology since 1980. He holds the rank of Professor and teaches courses in color perception and measurement, tone and color analysis, and quality control in the graphic arts.

Bob is active in a number of professional associations. He served on the board of the International Graphic Arts Education Association (IGAEA), the Technical Association of the Graphic Arts (TAGA), and the Inter-Society for Color Council (ISCC). He was the recipient of the 1991 GATF’s Education Award of Excellence, and the 1997 Gravure Education Foundation Exchange Professor. Bob also holds membership in Phi Kappa Phi, American Society for Quality Control (ASQC), and Graphic Arts Technical Foundation (GATF).