Color Lab
Reading: Land, 1977

This lab involves four Parts (Part IV is the longest!), which will introduce you to the spectral properties of light and the ways in which the cones and visual system extract/generate color percepts from them. You can organize the results of these parts into your lab report with a single introduction and discussion, and four parts to the results. You can address the “answers” to the specific parts within the body of each results section.

Part I. Computer phosphors are called “red”, “green” and “blue”. Using the PR655, generate a spectral emission curve from each of these, using an LCD display (laptop monitor). Print the curves; label your axes and the graphs.

Part II. Paint four pieces of paper: one with red paint, one with blue paint, one with mixed blue and red, and one with a manufactured violet. Measure the spectra using the PR655. Is the “violet” paint appropriately labeled? In your answer describe in physical terms the difference between purple and violet. Why do you think purple is considered a “Royal” color?

Part III. Generate an emission spectra from a white sheet of paper under a tungsten light, under a fluorescent light, and beside a window during the day, with no room light (indicate whether there is direct or indirect light). What color does the sheet of paper appear under each of these circumstances? How do the spectra compare?

Part IV. Illuminate the Mondrian Display with the three slide projectors (projecting through red, green and blue filters) each set to half of maximum power. Identify a patch of the Mondrian Display that appears red and another patch that appears green. Measure the spectral distribution and luminance from the red patch using the PR655. Calculate the activation of the three cone types (L, M, S) caused by stimulation from this region of the Mondrian display. To do this, you will need to obtain the cone fundamentals (the absorption spectra of the cones) and resample the cone fundamentals at the same intervals as the measured spectrum. The cone fundamentals can be obtained from http://www.cvrl.org/cones.htm (use “Stockman and Sharp (2000)”, “Energy (linear)”, “1nm”, and “tabular”). An excel spreadsheet with these results, and a short matlab script plotting up the results is provided with this lab.

Once you have both the cone fundamentals and the spectrum sampled at the same intervals (e.g. at 380nm, 384nm, 388nm etc.), take the dot product of the spectrum with each of the three cone fundamentals. To do this, you multiply the relative absorption of the given cone type obtained at a given wavelength with the spectrum measured at that wavelength. Then you sum up the results of each of these calculations for each wavelength at which the cone has some significant absorption, and for which you have a corresponding spectral measurement. For a given spectrum, you should end up with three dot products: we would call them “$L_{spectrum}$, $M_{spectrum}$, $S_{spectrum}$” which would be the activation of the L, M and S cones in response to the measured spectrum. Intuitively, the resulting dot products show the relative overlap of the spectrum with the cone absorption curves, providing a metric of relative cone activation.

Now train the PR655 on a “green patch” and adjust the intensity of the three projectors until the relative cone activations produced by the three cone types is the same as it was when the PR655 was trained on the red patch. What color does the “green patch” appear now?

To motivate your investigations, and as topics for your discussion, you may consider addressing the following questions:

1. What is a “metamer”?
2. What are “cone-isolating stimuli” and how are they made?
3. How are these principles employed in generating the Isihara color-blindness test plates?
4. The visual system is able to compensate for the different illuminants and is “color constant”. Using your knowledge of the psychophysics of color (Land’s papers), do you think neurons in the parvocellular layers of the lateral geniculate nucleus are or are not able to bring about color constancy? Explain.
5. The neural machinery for color constancy also brings about local color contrast. Define local color contrast. Local color contrast enables the visual system to distinguish a shadow from a region of local color. Identify a painting (or photograph of a painting) by Monet in which he depicts a shadow crossing a local color boundary (for example a shadow cast across a path and green grass). How is the color modulated between the different surfaces in order to achieve the effect of a shadow rather than four different colors painted on the ground?