The Math of Art:
Exploring connections between math and color theory

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Abstract

Simultaneous contrast and extension are fundamental principles in color theory, which directly relate to mathematics. Color study includes study of the proportions of colors and their effects. Using these concepts of the interrelationship of proportions and color can broaden expression much like adding extra colors to a painter's palette.

1. Introduction

With the invention of the camera the role of an artist changed. Representational art became less necessary as a photograph could be taken, instead. This led artists to redefine the parameters of art. The art community was freed from the boundaries of realism. The stage was set for new movements, which created new ways of seeing, teaching, and making art. Discoveries in science and industry advanced the study of what is today color theory.

2. Simultaneous Contrast

2.1. **Chevreul: Contrast of Light Intensity**. In the mid 1800s a chemist with a specialty in dyes, Michael Eugene Chevreul, introduced his book, The Principles of Harmony and Contrast of Colors [1]. Chevreul noticed that a color's character changes; the same color can look lighter or darker depending on its juxtaposition to other colors. It is said that his "Law of Simultaneous Contrasts" was conceived in the tapestry (Gobelin) factory where he noticed that the strength of the black depended on what colors were next to it. This is simultaneous contrast of light intensity or light and dark.

Fig. 1: *Identical gray squares appear differently. The gray square on the white background appears to be darker than the square on the black background.*

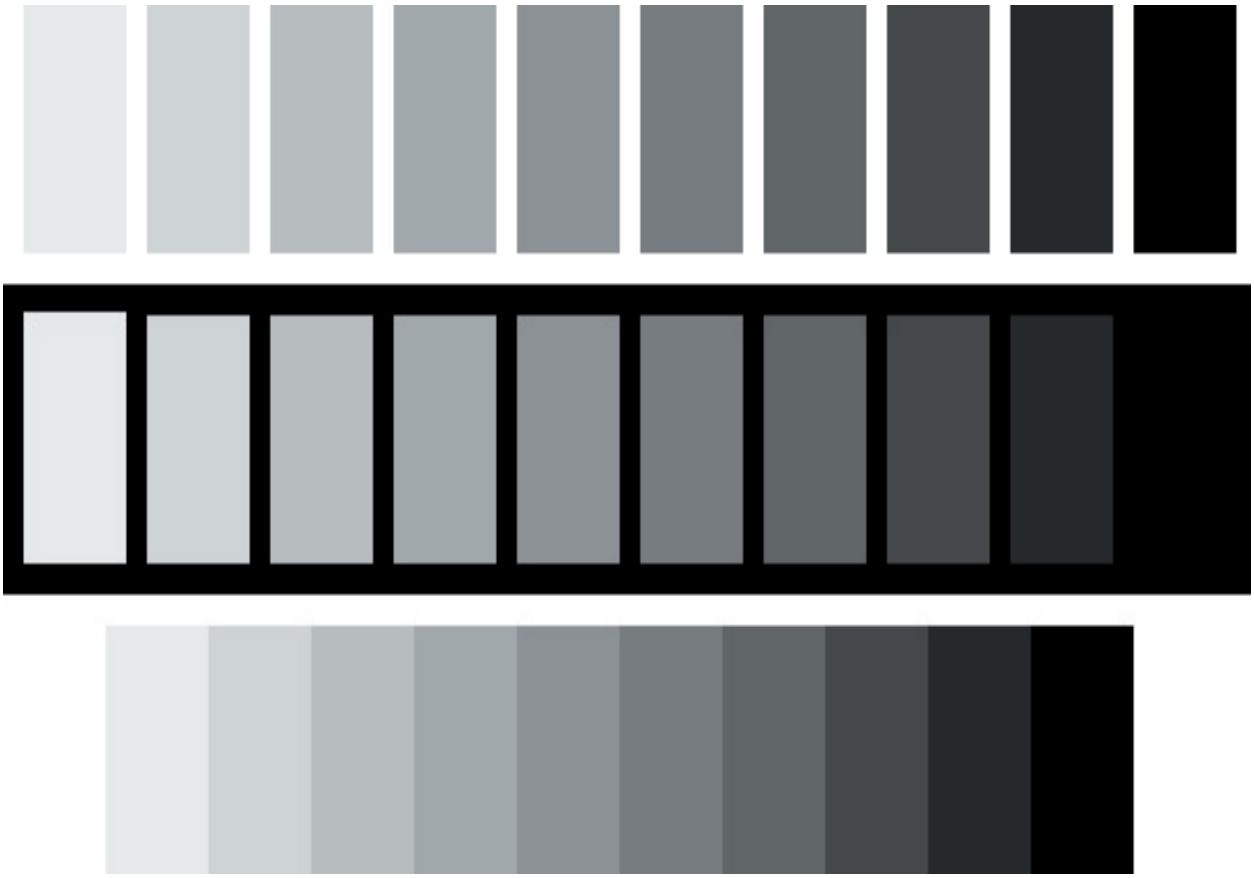

Fig 2: *Light/dark simultaneous contrast, using a gray scale. The gray scale on a white background appears differently than the same scale on a black background. When a gray scale is arranged linearly (lightest through darkest), another phenomenon occurs. Look closely at the boundary areas between colors; the same color looks both light and dark.*

Optical mixing, or blending color in the eye, was another phenomenon which Chevreul studied. The Impressionists and Pointillists investigated this technique. Looking close enough to examine the individual strokes or dots on a painting using this style reveals that the color that you see is not the color on the canvas. For example, green areas are made from blues and yellows, which mix in the eye.

Industry started to use this technique in printmaking using a dot matrix of colors to blend colors as we do today. This is referred to as Process color. All colors mix from percentages of four Process colors: cyan (C), magenta (M), yellow (Y) and black (K). The percentage of each Process color breaks down into a dot pattern for that color which ranges between 0-100 percent. Each Process color is printed as a separate color pass. When all four colors are combined there is a series of overlapping dots which create the final print. Color photographs in newspapers are printed in this manner. Pantone colors use the same percentages as process colors, however, rather than a series of dots, the color is mixed as pigment and printed as block color (without dots.) The Pantone colors are labeled using a number system. The standardization of Pantone and Process colors allows for more consistent reproduction of color. Black was added to the primary colors in printmaking to add more contrast and depth. Without black, objects appear "washed out".

2.2. Goethe: Contrast of Hue. The first notations on the "light value" of colors were done by Goethe. Had Chevreul had access to Goethe's work, he would have made use of these light values in his "Law of

Simultaneous Contrast". These "values" or proportions were derived from observation and are still being taught today. In the correct (harmonic) proportions each color will have equal light value. For example, take yellow and purple. Yellow is very bright. Purple is darker. A much larger area of purple is needed to emit the same amount of light that an area of yellow does. This is contrast of hue. The hue is a pure color without white or black. The following proportions were derived from Goethe, elaborated on and taught by Johannes Itten and Josef Albers. Albers taught color theory after Itten at the Bauhaus and later brought these ideas to the United States

a. green / red 2:2 | b. blue / orange 2:1 | c. purple / yellow 3:1

Figure 3: *Simultaneous contrast quantified such that the light intensity of each hue and the area are proportionate. Each color is shown in relation to its complement. 3a represents the light values of green/red, which are equal. For every 2 areas of blue, one area of orange is harmonic in 3b. In 3c, it takes 3 areas of purple for every one of yellow.*

The proportionate areas for the primary and .secondary colors are:

green	:	blue	:	purple	:	red	:	orange	:	yellow
6	:	8	:	9	:	6	:	4	:	3

To use these areas in harmony, the chart is used as follows: for blue / yellow, use 8 areas of blue for every 3 of yellow….8 : 3, etc. There is more detailed reading about these proportions in Johannes Itten's The Art of Color [3].

These proportions were combined with Chevreul's initial observations to make the "Law of Simultaneous Contrasts". Simultaneous contrast includes both contrast of light intensity and contrast of hue.

3. Extension

Using these proportions creates harmony. Deliberately creating ratios that vary from the above chart creates a tension that is called "Extension" or "Proportion of Color". For example, imagine a painting with predominant proportions of blues and purples; add a small orange line and the orange line stands out predominantly. This is the use of the proportion of color. It is a tool to create effects by the limitation or expanse of color by choosing to work with non-proportionate light values. This tension is actually a lack of equilibrium.

Physiologically, the eye wishes to make equilibrium. Creating equilibrium from the imbalance, the eye generates another image called an *afterimage*. The afterimage is always the complementary color of the color viewed. It is strongest with the greatest contrast between the colors. The afterimage is believed to be a result of retinal fatigue. For example: After looking at the color yellow for a protracted time, the color sensors in the eye "burn out", the eye generates the color opposite, purple: this is the afterimage.

Simultaneous contrast is effected by the afterimage even though this image is not a "solid" image. The blending of colors, whether by optical mixing (yellow/ blue areas making green), or by afterimage, are powerful tools that can be manipulated.

4.Shifting Color

"*A color has many faces*" –Josef Albers

Just as the same middle gray could appear lighter or darker, so can the perception of the same color shift. A color is relative to its surroundings. The most basic shifts have to do with contrast of light intensity or contrast of hue. The secondary (orange, green, purple) colors, as well as other colors which are combinations of two or more colors, lend themselves easily to a shift in appearance. Consider a picture plane divided into two colored backgrounds: one red, one blue. Placing two squares of the same purple color on both background colors makes the purple appear as if it is two different colors. The color has not changed, just its surroundings. Purple is made up of portions of both red and blue. In comparison to red, purple is more blue. On the red ground, the blueness of the purple is apparent. On the blue ground, the redness of the purple is apparent. When juxtaposed next to blue, the quantity of blue in the purple is less than the amount of blue in the blue, therefore, the purple appears more red in contrast.

5. Conclusion

Color can be manipulated the same way a mathematical formula. Using various proportions of color can create harmony or dischord (tension). Until one is familiar with the variables in a formula, the equation is not complete. Knowing the variables of simultaneous contrast and extension facilitates an operative knowledge of connections between the art of color and math.

"Give me mud and I will make the skin of a Venus out of it, if you will allow me to surround it as I please"
- Eugene Delacroix

Bibliography

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