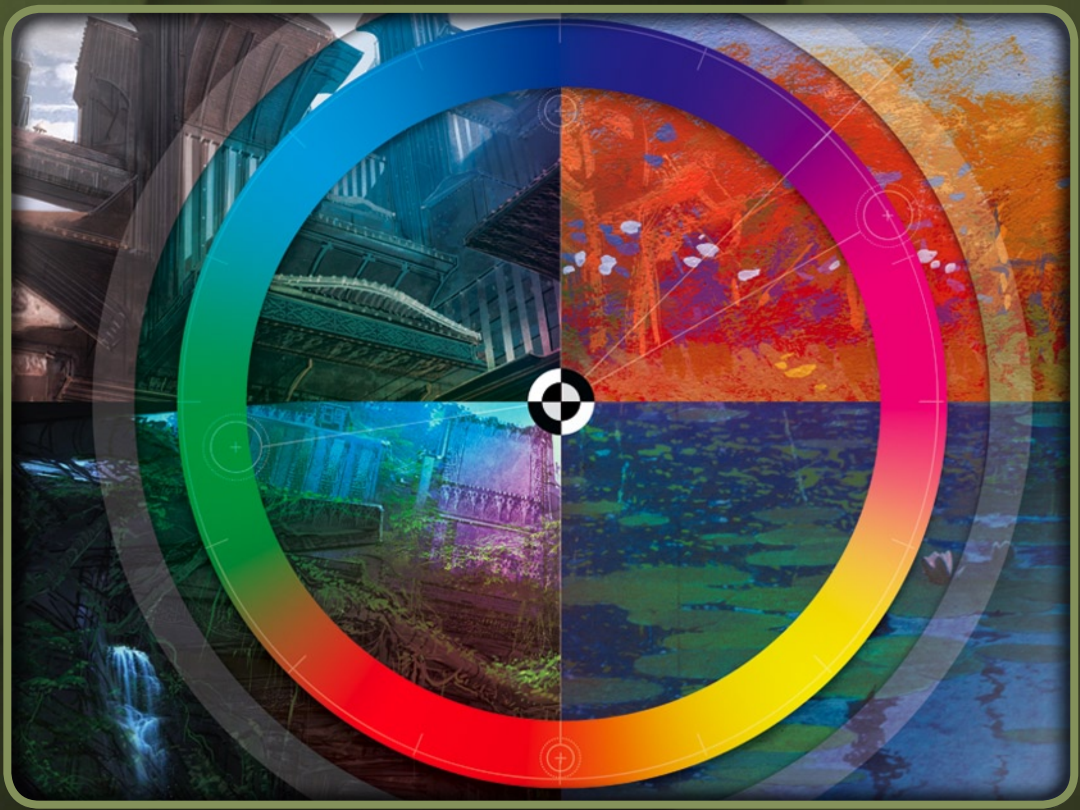
LECTURE NOTES

COLOR THEORY: THE MECHANICS OF COLOR

Applied and Theoretical Color with Richard Keyes



This DVD is devoted to helping you understand some of the mechanics and vocabulary of how artists and scientists have defined and shaped the concept of color.

I'm going to jump right into one of the essential problems with this subject—just what is color?

Does color reside in objects? Does this red object contain color? The answer is found in another related subject—light. We are looking at this calculator in an environment lit with white light, and, in that situation, we would call this a red plastic calculator. But when I take all of the redness out of the light (we are left with the color cyan), the calculator looks dark gray. I didn't change the object, but subtracted the one element from the environment that created its redness. The color was never in the red plastic, it was in the light. We owe this realization to Isaac Newton, who published his findings on light and color merely 300 years ago. Whether that light moves in waves or particles is a question for the quantum physics experts to answer, and it is tangential to our subject of color.

When Newton conducted his famous experiment with a prism, he was not the first person to show that a prism can display colored light. But his predecessors thought that the prism added colors to white, and Newton thought that all of the colors were in the sunlight already, and that the prism opened them up so that we can see them individually. Anything we call a color already exists within white light.

So, color is light—yes? Well, not so fast. That light enters our eyes, changes chemistry inside our retina, and sends an electrical message to the brain, which processes that information in numerous areas before we can open our mouths to say, "red Hello Kitty calculator." Color is a sensation created in our eye, and processed by the brain. Since everyone's brain is not the same, and everyone's eyes are not the same, we all see color somewhat differently, but sharing a language allows us to tell ourselves that those differences are manageable.

In fact, 8 1/2 percent of the world's population suffers from one kind of color deficiency or another. We call that color blindness, but the inability to see any colors at all is an extremely rare phenomenon—only 0.003 percent of the world's population cannot see any color. The most common kind of color deficiency is the reduced perception of green we call deuteranopia. 4.9 percent of men suffer from this, and about 1/2 of one percent of women (color deficiencies are definitely centered on guys). If you do suffer from a color deficiency, it doesn't need to get in your way. Many artists are color-blind, and some of them may be favorites of yours.

Vocabulary

Anything we call a color has three attributes or axes. These are known as value, saturation and hue. If the surface or light source you are looking at does not have these three essential qualities, then it is not a color.

Value is the simplest to talk about, since value is simply dark and light differences. Every color reflects or projects varying amounts of light, and there is no absolute standard for the correct amount for any chosen hue. One cannot say, "We can't use purple for this problem because purple is too dark," since all you have to do is add some white to it to change the value. The hue is still purple, even in its higher value form. There is not a lot I need to say to explain what value is—you have already lived a life that has described basic differences in the world based on value. But value is what our brains crave, not color. We can watch a two hour black and white movie and not think about the missing hue and saturation elements even once. We use value to distinguish form and to create the edges that we, as human beings, want to rely on to build the world in our brains every second. We can still see textural differences, spatial differences, tactile differences and edge-based differences with value alone. The large majority of the neurons in our brain devoted to sight are concerned with value, not hue or saturation. It is so important to our understanding of the world, that we use phrases such as, "I need to see it black and white," as a way of validating the impressions we have.

Saturation is simply the purity or intensity of a color. It is not a difficult concept to grasp, but the word "brightness" confuses the subject, so we will avoid using it in the context of color. Brightness can mean both the intensity and the high value of a surface—for instance, a dull yellow can be described as a bright color (especially if it is seen next to a dark color), without being very saturated at all.

Value and saturation are not attached concepts—a color can change its saturation, but leave its value unchanged. We live in a world in which high saturation is easily available to us, and it is readily assumed that intensity is an expected attribute of any hue. But this wasn't true for the majority of human history. It is only in the last 200 years or less that we have luxuriated in the range of saturation that chemistry has afforded us. Before the early 1800's, a pigment might be valued primarily for the high saturation it exhibited. We now think that saturation is a concept that can be applied to any hue. This way of thinking was codified by Albert Munsell in the first decade of the 20th century, and would not have occurred without the advances in pigment and dye manufacturing that came about in the 19th century.

A Pantone fan deck can illustrate this concept of saturation. The most saturated hue for all of the samples in the front of the fan deck is always in the middle. The three samples above the midpoint all have white mixed into them. Any saturated color mixed with white is called a tint. The three colors below the saturated middle are called shades (a color is a shade when black is added). In the back of the Pantone fan deck is found another organization of colors. All of these are examples of a single color which has had various degrees of gray added (which is called toning a color. A color with gray added—whether the graying came from a gray pigment, or whether the color was neutralized with its opposite color—is called a tone).

I heard someone say once that saturation is color straight from the tube, but that is not true. Saturation is a perception, a sensual reaction. Squeezing gray paint out of a tube doesn't make it saturated just because you haven't added anything else to it yet. It is true, though, that anything you mix into a paint will desaturate it.

Another inference we can make from this is that white, gray and black are not colors, because they have no saturation. There are arguments that can be stated against this, but I want to recommend that you think of the three achromatic colors I mentioned as lightening, dulling and darkening agents rather than individual colors.

The confusion comes from the fact that white, gray and black are hues, but not colors. So, what is a *hue*?

Of the three axes of color, hue is the most contentious to define. The world of physics defines hue as vibrational energy, existing in the electromagnetic spectrum between about 400 to 700 nanometers. The electromagnetic spectrum is the entire combination of energy we get from the sun, and the 400 to 700 nanometer span (a nanometer is a billionth of a millimeter) is about one seventieth of the whole thing, but it is the only part we can see, so it's the part we are most aware of. You are aware of this spectrum when you are looking at a rainbow, which separates the component parts of white light so that you can see each one. There are problems with this definition, though—not all colors can be found in it. For example, the spectrum does not contain pink, brown or purple, and it also assumes that all hues are highly saturated. Visual creators would have a hard time using this organization to make color decisions.

A second definition of hue comes from art schools and states that hues are the colors on the outer rim of a color wheel, usually a subtractive color wheel. At least this is an improvement, since we now have access to purple as a color, but the fatal flaw of only considering saturated colors as hues is still dragging us down. There is no brown in this definition.

A third definition of hue is simply the name of a color. This is the most intuitive and common sense based definition since, when most people refer to a color, they are nearly always referring to its hue, and ignoring saturation and value. This is so true that when I have asked many students what they think hue is, the answer I hear is that, "Hue is the color of a color."

Not all names are language-based. Some names use codes, such as 5R12, which stands for a saturated red in the Munsell Color System.

We can adapt the art school subtractive color wheel to illustrate this larger definition. Art schools are generally interested in hue relationships on the subtractive color wheel, but when the wheel is filled in with all of the color information, we can see that a line drawn from the center of the color wheel, and extending out past the saturated ring is one single hue. The hue is not just the dot where the line intersects the saturated rim.

Primary Colors

"What are the *real* primaries?"

Art School academics occasionally get into arguments about which set of primary hues are the real ones—that is, the ones we should be teaching. The question results from the uncomfortable use of the word "the" (as in "the real primaries"), and also the idea that art can be described, formulated and validated by scientific principles. We assume that answers we get from science are absolute, even though very few scientists think in absolute terms.

We think of primary colors as colors that cannot be mixed by combining other hues, or as the starting point to mix other colors from. The idea is a relatively new one, first written about in the seventeenth century. Before then, hues were indicated by their relative value. Aristotle was the first to organize hues this way, and his arrangement looked linear and vertical. Value was the only organizing factor in this arrangement, which is why you are looking at purple next to green, as if there was a hue-based reason to make these two colors neighborly. Hues were considered to be attached to an innate value, and any deviation from that innate value was just a dimunition of the power in the color. Robin's Egg Blue would be considered a weak version of blue, in this way of thinking. Lapis Luzuli, now there's a *real* blue.

Color Systems

Humans have been trying to figure out "how color works" for over two thousand years. The first person to write about it from an observer's point of view was the philosopher Aristotle (previous philosophers wrote about color, but only as a concept that could be used analogously to understand the cosmos, and artists didn't write much about color). Aristotle wrote that there are seven basic colors, because an earlier philosopher—Pythagorus—insisted that seven is the number that makes the universe go 'round. He organized these seven hues in a straight line which held the lightest values at the top, and the colors darkened as they travelled to the bottom. This organization is based entirely on value and seems unusual to us, because we now base our color organization on hue. But, unusual or not, it served European culture for about two thousand years, and wasn't challenged until Isaac Newton.

In the late 1600's Newton not only proved that light was made of all colors, but went further to connect both ends of his spectrum to make a circle. He had to add a red-violet in order for the end closest to infrared to transition into the end closest to ultraviolet, since red-violet is not part of the spectrum. But he did this in order to pay homage to another, earlier philosopher, Rene Descartes, who had constructed the model for Newton's color wheel. But, Descartes was not concerned with color—he was mapping out the seven note scale in music.

It is often claimed that Newton invented the color wheel, but he had little interest in helping out artists, and only wanted to show a metaphorical organization of color. It was many decades before another writer noticed that, on this Newtonian color diagram, one could find the opposite of any color. This realization was the beginning of science informing art about color, although it would still be another 150 years or so until what we think of as the color wheel became a regular fixture in art school classrooms.

Now we are aware of a multitude of possible color wheels, but there are two of them which we rely on most often. The first is the subtractive color wheel, which I have already referred to. It is called subtractive because, when one mixes colors from one part of the wheel with colors from any other part, the mixture will be darker than the lightest of the two mixing colors. The mixture subtracts the amount of light that can be reflected off the paint or dye. That last part is important, because the subtractive color wheel is concerned mainly with what happens when physical elements interact, such as pigments and dyes. The subtractive color wheel in no way helps people understand "how color works." It can help you understand how physical colorants mix, it is especially good at defining complements, and is the basis of the art school idea of color harmony.

The first concept to grasp in learning this color wheel is the idea of primary colors. Primary colors cannot be mixed from any other colors, but most other colors can be mixed from the primaries. We have been taught from childhood that the primaries are red, blue and yellow, and that all other colors can be mixed from these three, but you have probably learned by now that this is not true. The words *red, blue* and *yellow* are very general color terms, and can even change from culture to culture (many Asian cultures, for instance, do not differentiate between blue and green), and only some fairly specific red, blue and yellow hues allow us to mix a wide range of other colors. Those best versions of red, blue and yellow are called magenta, cyan and yellow, and I will come back to them in a minute. There are no such things as the "real" primaries, since most all of the color wheels we encounter are constructed for a specific usage. Some color wheels, especially the system called "The Natural Color System" (or, NCS) consider green to be a primary color equal to the three we just mentioned. We will stay with red, blue and yellow for now.

Once these are established at equal distances from each other on the wheel, we can place markers for the secondary hues at exactly the halfway points between the primaries. That statement about being halfway is not a promise that 50% of each of two primaries will create a perfect secondary. Perceptually, the secondaries should look as if they are made that way, but all paints and dyes will mix differently, so there is no absolute formula. It is only where we place those colors due to convention. Remember, the subtractive color wheel is not science. It is a metaphorical map.

The primaries and secondaries are the most important and most referred to aspects of a subtractive color wheel, but in the interstices between each primary and secondary are hues we refer to as tertiaries. When referring to these colors, you are advised to label them with the primary first, and the secondary name second. For example, "red-violet" is preferred to "violet-red."

This is the dominant color wheel taught in art school because students can create one with paint. It is not because it is closer to the truth than other color wheels. When we get to the subject of color harmonies, the subtractive color wheel will come in handy again.

HARMONIES

I have been teaching Color Theory for about seventeen years, and I have observed that students new to the class seem especially anxious about learning color harmonies. There seems to be an assumption that color harmonies are art laws, set in stone millenia ago, when they are actually a twentieth century phenomenon.

Color, in the middle ages of Europe, was used to glorify God. More specifically, color was considered to be raw material in mineral form from the earth that has been so artfully refined that the painting was considered to be a large (flat) jewel. Naturalism and meaning were not considered as important as they are today. All meaning was to be found in the Bible, and the painting merely points to those meanings.

In the European renaissance, naturalism began to replace the previous symbolism of color usage, and this worked well for artists for the next few hundreds of years until the French Impressionists challenged color's use in the ninteenth century. The Impressionists were aided by the recent discovery of photography and by the many newly crerated pigments and dyes made through the new industry of chemistry. The Post-Impressionists again challenged color usage by attempting to allow colors to mix in the viewer's eye rather than mixing on a palette. Eventually, pure abstraction would lead color usage so far away from the naturalism of previous centuries that the need for a systematic organization of color was approached by numerous academics. When the dust settled, color harmonies began to be taught in schools.

It is important to note that color harmonies were taught in art schools, where color was manipulated by means of paint. Since paints and dyes are best understood through a subtractive color wheel, then that was the color wheel that was taught. This fact is the source of confusion many people have concerning the differences between additive and subtractive color wheels. Additive color wheels address how our eyes and brain process color and how light reveals color to us. Subtractive color wheels address what happens when a person mixes pigments and dyes together. The litany of harmonies I am about to go into are mapped on the pigment (subtractive) color wheel, even though you receive color through additive means. The subtractive color wheel makes these "maps of beauty" easy to rationalize, and our culture has lived with this idea through enough generations that we accept the subtractive color map as truth.

Monochrome Harmony

If the word "harmony" refers to the world of music, the idea of a monochrome harmony would relate to the idea of a single pitch. Monochrome harmonies are not harmonies at all, but value-based compositions that contain only one hue. There are no hue relationships in a monochrome harmony, only saturation and value relationships.

Analogous Harmony

Analogous harmonies contain more than one hue, but all of the hues in this kind of harmony are neighbors on a color wheel. The effect is close to that of monochrome harmony, but richer. In fact, if I see that a student is having a hard time learning harmonies, I suggest that analogous and complementary harmonies are the easiest to start with.

When you observe an image through a color filter (sunglasses, sunset light, a painting seen through varnish), only similar hues will be able to get through the filter, giving the impression of an analogous harmony. This effect is called *dominance of hue*, and is related to the harmony we are talking about here, but it is not the same thing. In *dominance of hue*, only one hue can be saturated (the hue of the filter), and the further any other hues are from the hue of the filter, the less saturated they will appear. Also, whites will be the color of the filter.

Complementary Harmony

Color theory contains two similar concepts—complementary harmony and complementary contrast, and they are often seen as interchangeable. This is confusing, so I recommend separating the two in the following way.

Complementary harmony, as the name implies, is intended to unite opposites and create a harmonious union. Starting with only two opposite hues, the colors are mixed together, creating browns and grays that serve as transitional elements separating the two opposites. One can create an entire believable world with only two colors, but the secret is to avoid putting them together to show how different they are from each other. Emphasizing differences is what contrasts do.

Triadic Harmony

Any three hues that are equally distant from each other on a subtractive color wheel are the basis for a triadic harmony. The most easily recognizable and basic of triadic harmonies is the simple combination of red, blue and yellow, although triads can be made from secondaries and tertiaries. Triadic harmonies usually look simple and bright, and are often used to make an idea easily digestible.

Double Complementary Harmony

Double complementary harmonies are simply two sets of complements. You are advised to allow one of the two complements to dominate the other, and even allow one of the dominant pair to have the strongest impact.

Double complement is the essential palette of eighteenth and nineteenth century landscape painting, with red/green combinations in the foreground, and yellow-orange/blue-violets in the background. Nature was the model for the concept of harmony in general, and paintings assumed that color should encompass the spectrum.

Triple Complementary Harmony

This is rare and can lead to chaos, but research for the DVD pulled up some samples. The successes are based on the idea of complementary pairs grouping in proximity.

CONTRASTS

Harmonies are only concerned with hues. They are ingredients, but they are not compositional tools. These seven contrasts, first published by Johannes Itten, are compositional tools. Learning how to artfully use the following seven ideas will assist your efforts far more than learning harmonies will.

Contrast of Value

Probably the most obvious of the seven contrasts, but underestimated. We see much more due to value than to color, to the point that value contrasts will change our perception of color faster than any other means. When we see a color image with very strong dark/light contrast, we may not even notice the color. The value contrast seems to be enough to satiate the brain, and no more is asked from the experience. Nothing will disturb an otherwise lovely composition faster than a questionable value relationship. If you don't get contrast of value right, then go back and start again.

Contrast of Hue

Although color contrasts are compositional tools, contrast of hue tends to disrupt a composition. It's raison d'être is "look at all the different colors!" There is no sense of color grouping involved with this contrast. The main idea is to try not to put two similar hues next to each other. Leroi Neiman and Peter Max are exemplars of this technique, as were the illuminators of medieval manuscripts. National flags also separate their hues as much as possible.

Contrast of Temperature

Warm and cool contrast barely needs an explanation, since we so easily reach for it as a common distinguisher of hues. This contrast is also the most metaphorical of the seven. There is nothing inherently warm about a red-orange, but we have learned sometime in our life that things that glow red-orange can be painful to touch. Blue is the color of the sky and water (and glacier ice), all refreshing experiences.

I don't believe that every hue has a right to a warm and cool version of itself. There is a such a concept as a warm red (vermilion) and a cool red (magenta). But, can you imagine a cool orange? Or a warm blue?* I have heard numerous artists refer to the amount of blue, yellow or red in a hue as it's temperature

Contrast of Proportion

Itten calls this contrast of extension, and he was using this idea to advise artists to use contrasting colors in the "right" proportions. The proportions are based on value—red and green can be used in equal amounts, since they are close to the same value. A Blue and orange relatioon should be 2/3 blue and 1/3 orange. By the same logic, a yellow and violet relationship should favor the highest value hue (yellow) for the smallest portion of space. One quarter to three quarters, in fact.

We no longer make compositions based on the universal assumption of using opposites, at least not as much as the world did eighty years ago. This contrast is used in the more general sense of small to large amounts of color usage. The paintings of Hans Hoffmann are often sublime examples of this, as is the work of many color field painters.

Contrast of Saturation

Contrasting intensity against dullness is what is emphasized in this category. A human eye is always drawn to the strongest edge created by light/dark value, but that eye will linger longer on the most saturated area of a composition. For creating emotional impact, or for simply juicing up the effect of your image, contrast of saturation is very useful. I actually think contrast of saturation is the most overlooked of all seven of these contrasts

Complementary Contrast

This is easy. Putting two opposite hues next to each other so that they each make the other color look more intense is a natural human inclination, and we have been doing it for hundreds of years. Some theorists have stated that we feel a sense of closure when we are looking at a balanced selection of hues (meaning that at least the majority of the spectrum is represented in what we are looking at), and conversely, that we experience a sense of incompleteness when most of the hues in our field of vision favor only one part of the color wheel.

Simultaneous Contrast

There may be no other subject in this list that is more important than this idea—colors are defined by their neighbors. This is an absolute statement about the absence of absoluteness in defining colors.

We often imagine that there are "accurate" versions of colors, as in the phrase "true blue," but everything that we call a color can be manipulated simply by putting another color next to it. And not just hue, but value, saturation and even temperature can all be modified with the arrival of the appropriate neighbor. And, you have most likely never seen a color that didn't have a neighbor.

You can lighten a color by putting it against a dark background, you can cool a color by putting a warm color against it and you can dull a color by putting a more saturated version of itself next to it.

This is not a choice, as are many of the other contrasts. You cannot design a composition that does not contain simultaneous contrast, which is why understanding this one principle is so important.

**Green is an anchor color—a psychological primary. When a blue leans towards green it is a greenish blue, not a yellowish blue. I cannot consider green to be a warm hue.*