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SENSATION AND PERCEPTION

how color influences flag design

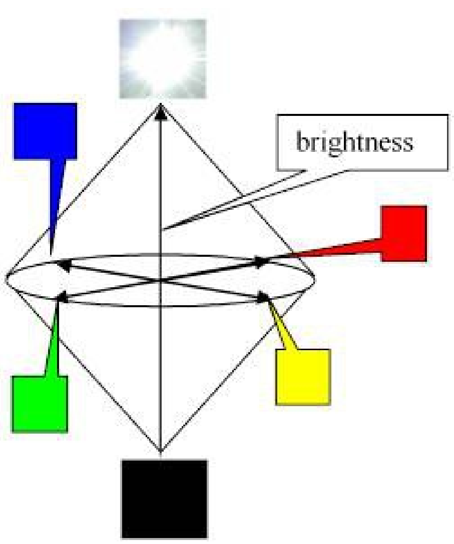
by Richard R. Gideon

It is no secret that the most commonly used colors in flag design are red, blue, and white; look at any national flag from any country in the world and the odds are you will find at least one of them represented. Technically, white is the combination of all colors, but it is usually identified as a category selection on most color charts. Given the fact that specific colors are actually electromagnetic radiations, the human eye is sensitive to individual wavelengths of light, and that the eye is not uniformly sensitive to all wavelengths of color, why do flag designers choose the colors they do; and more specifically, given the fact that the human eye is most sensitive to colors in the yellow/green spectral region why don't we see more yellow or green flags? This article explores not only these issues, but the difference between the sensation of color and how we perceive it.

First, let us establish some working definitions as they will apply to this study[1]:

1. SENSATION refers to how we measure our capacity to detect small changes in stimulus, and
2. PERCEPTION is concerned with how we use sensory capacities in everyday activities

When one studies the genesis of most flag designs one finds that the pattern and color scheme employed are rarely selected on the basis of how well the flag will be seen; rather, they are chosen based on the message the flag designer wishes to send. That the color red has been associated with courage and blue with fidelity are well known facts. But it is doubtful that the flag designer employing such colors has given much thought to how well they may been seen in a variety of light conditions. Whether this is the case, what is true is that a flag must have at least two colors if it is to be useful: a red flag with red letters and a red cross, all of the same hue, is hardly effective. Not only must a flag have at least two colors, the difference between the hue of the colors must be enough to be seen in a "normal" light setting.[2] To appreciate this one must consider the properties of light and color, and the wonderful receptor known as the human eye.



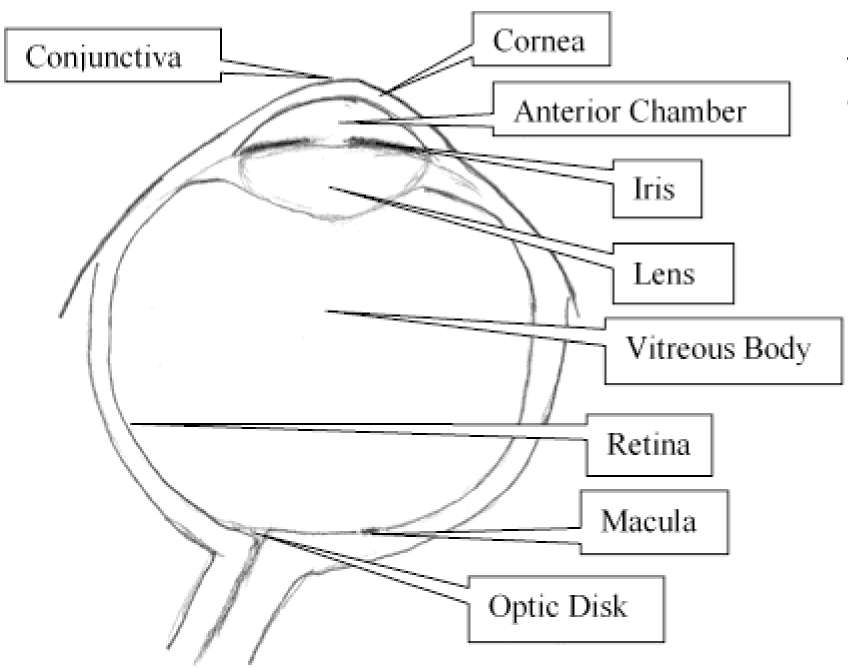
SENSITIVITY

The figure at left shows the relationship between color and intensity. The black square represents the complete absence of any visible electromagnetic radiation (a.k.a. light). The vertical line in the middle of the diagram represents brightness or the amplitude of a light wave. More specifically, the vertical line is showing all individual colors increasing in amplitude together. This would produce a line of color going from black, through various shades of gray until a full bright "white" light is seen (top of the diagram). However, if one were to start at black, and produce a SINGLE FREQUENCY electromagnetic wave it would be seen as an individual color, known as a PRIMARY color. (Combinations of electromagnetic waves produce different colors.) Increasing the intensity of this wave would make the color more vivid until it reached SATURATION. Selected points of saturation for blue, red, yellow, and green are shown on the diagram (not to scale). These points represent the highest amplitude of a given color in which no "white" (equal amplitudes of all other colors) light may be found; i.e., pure color. From that point on the only way to increase the intensity of the light is to increase its "brightness," or mix in white light to increase the intensity.

Although the physics of light is independent of human beings, how we see things, and our sensitivity to light, is axiomatic for any artist or flag designer; after all, there would be no reason to create these things if they couldn't be seen. Therefore it is important to study how we see, and how we interpret what we see. And while it is the brain that actually does the seeing, it is the eye that is the portal to the brain.

The human eye is extremely interesting, and one could spend many years studying its parts and operation. For this paper we will offer a brief overview of how the eye operates, and concentrate on the eye's response to various wavelengths of light.

The basic parts of the human eye are the conjunctiva, cornea, anterior chamber, iris, lens, vitreous body, retina, the fovea centralis in macula lutea (or simply macula), and the optic disk connection to the optic nerve. There are also a number of muscles, blood vessels, and other necessary parts that we will have to pass over, but are essential for movement and protection. Each of the parts listed has a specific function, to wit[3]:



Conjunctiva: a coating over the eye that acts as a "sentinel", giving warning to even the slightest irritation

- Cornea: a thick and relatively hard elastic coating which acts as a "window" for the eye's interior
- Anterior Chamber: a area of liquid acting as a buffer between the cornea and the lens
- Iris: part of a muscle called the choroid, and used as a kind of curtain to adjust the amount of light admitted to the interior of the eye. The color of the iris is responsible for "eye color." The opening in the iris is called the pupil
- Lens: responsible for focusing light onto the retina
- Vitreous Body: the largest volume of the eye, consisting of a jelly like material
- Retina: the eye's "screen"; the part of the eye where the image is focused and formed (upside down)
- Macula: a yellow spot on the retina that is the area of most acute vision
- Optic Disk: the connection to the optic nerve, which in turn connects to the brain. The optic disk is sometimes called the "blind spot" because it is not sensitive to light.

When parallel rays of light enter the eye they are brought to a focus upon the retina. It is essential for clear vision that proper focus occurs; however, not all human eyes develop ideally, and as we age some of the automatic adjustment mechanisms do not perform adequately - but these are all subjects for another forum. In a correctly operating eye objects between 4 inches and 70 yards distant(!) are automatically accommodated and focused onto the retina. Objects greater than 70 yards may be regarded as emitting practically parallel rays of light and require no compensation.

We now concentrate on two aspects of the eye that are important to theme of this paper: sensitivity to light intensity and color. The apparent brightness of an object depends upon the amplitude of the electromagnetic radiation that the object either emits or reflects. The eye is remarkably sensitive to both intensity and duration of light, responding to a stimulus in a fantastically short period of time, but holding to the image for a relatively long time. Fechner's[4] psycho-physical law says that "the smallest perceptible difference bears a nearly constant ratio to the full intensity of the bright objects."

The macula's role in color sensation is extremely important. This part of the retina is the most color acute, resolving over 200 tints, rendering them with different intensities even though the physical amplitude of each color is the same. It is here we find that yellow (more precisely, the yellow/green spectral line) appears brighter in normal light[5] than an equally intense red or blue. As light intensity (or amplitude) decreases different colors fade away at different rates, so that the ratio in Fechner's Law is different for each color. Red and yellow disappear first, and blue last; thus in dim light blue is the brightest. Combine the eye's non-linear response to intensity and it's color discrimination abilities and one comes to some interesting numbers:

- As above, over 200 tints around the macula
- Just discriminable hues: 156
- Discriminable brightness: 572
- In the yellow to blue/green spectrum the eye is able to distinguish a difference of 1 millimicron in wave length
- Taking into consideration the eye's ability to respond to "just noticeable" differences in hues and intensity, the estimated number of colors sensible to the eye is estimated to be in the neighborhood of 300,000![6]

Another important point to adduce is that the human eyes gives up color for detail. This is particularly true when objects are at a distance. In layman's language, we simply don't see the colors on small sections of an object when the object is "far away." The eye sees the detail in "monochrome," or better said, the eye perceives the amplitude of the light reflected by detail uniformly - thus as a grayscale image.

To summarize:

- The eye responds to hue (a function of the wavelength of electromagnetic radiation) and intensity (a function of BOTH an electromagnetic wave's amplitude and wavelength)

- Individual colors have specific wavelengths, but combinations of wavelengths produce differences in hues and intensities

- Yellow/Green colors are the easiest seen in normal light

- As an object is moved away from the observer its detail loses color, and blue retains its hue longest as the amplitude of a color is decreased

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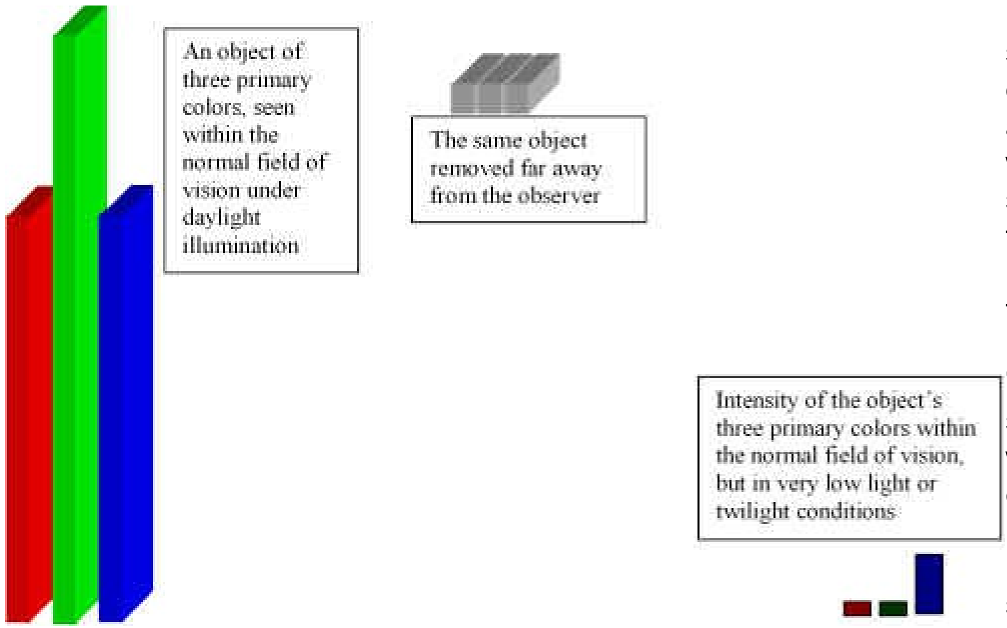
PERCEPTION



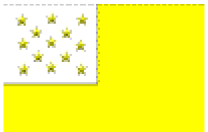
Perception is our ability to use sensory capacities in our everyday lives; or to put it another way, perception is how we humans decide to act upon a stimulus. As such, we must be taught what a color means, and in doing so it is the human being that makes the determination. A piece of red fabric may recall a "danger" signal, a dress, or some human characteristic that we find desirable, such as courage. Sometimes the laws of physics will help us to assign meaning to color. As we have seen, the eye is most sensitive to electromagnetic radiation around the yellow/green spectrum, and the RATIO of sensitivity is very large. Thus it is that scientists conducting experiments with color have found that while yellow is easy to see, if it is raised in intensity too much it becomes an irritant.

Traditionally, red, orange, and yellow are called "warm" colors while green, turquoise, and blue are called "cold" colors. But why? One common explanation is that "reds" come from fire - the burning of wood by various cavemen - while "blues" come from the hue of glaciers. We say "red hot" and "so cold he turned blue." Certainly some flames are red, and some ice is blue; but a gas flame is blue and certain leaves turn red when chilled. One may consider that the mind has a large bearing on this issue, since perception, not only of color but of many other physical things, is a term of psychology. And since our minds are influenced by the world around us, culture helps determine the way we perceive color.

One must be careful not to divorce perception from sensation, of course. If we learn to association meaning to color, but color is subject to change with such physical properties as light and distance, then one may logically conclude that the initial perception of an object is influenced by sensation and not get much of an argument. Certainly an artist working in oils understands this very well. By working various colors and shapes into a painting the artist may suggest the dimensions of depth and even time on a two dimensional canvas.

Now we come to the crucial question: Since it is know that the yellow/green spectrum is the easiest to see, why are so few flags designed using these colors? The answer may be as simple as "the heart overrules the head," an argument that any couple in love can recognize. Flag designers may simply employ colors that they like because they like them; and that is that. Adducing science to prove that either yellow or green decay rapidly in the eye as the light fades does not seem like much of an argument against the use of these colors when one considers that most nations suggest (or require) their flags be removed from display at night, or lighted so they may be seen. Years of cultural suggestion seem to have established that the "color code" trumps science. RED = valour, WHITE = purity, BLUE = fidelity, YELLOW = cowardliness or sickness, GREEN = health, BLACK = death. If one were asked to design a flag, and had this "code" in mind, one would probably be inclined to use it. It is also quite possible that the flag designer is constrained by the requirements of the client; a person who has not given thought to how colors will be perceived because the devices on the flag are of paramount importance. A company wants to use their "horse motif" - two rampant black horses on each long side of a red oval - on a dark blue field. But black doesn't contrast well against a dark blue field. Why would someone insist on this?[7] Probably because an initial paper sketch or graphic looked good - inches away from the eye. But a "poster" often makes a poor flag, and visa versa. Flags designed by committees very often fall into this trap. This writer has been told that "designing a flag isn't rocket science." That is true; but it IS science.

In conclusion, and begging the reader's patience, the English Rock and Roll band "The Moody Blues" may have solved the entire issue without knowing it, and I'll let them have the final word via a lyric from their "Days of Future Past" album:



Cold hearted orb that rules the night,
Removes the colours from our sight;
Red is gray, and yellow - white;
But we decide which is right - and which is an illusion.

Notes and comments:

1 - THE AMERICAN PEOPLE'S ENCYCLOPEDIA, Karwoski, Theodore, p17-466. The five classical senses are: 1) vision, 2) audition, 3) taste, 4) smell, and 5) touch. These senses are also known as *modalities*.

2 - It should be noted that lighting on an object is influenced by distance the object is from a light source, and the distance the observer is from the object. The basic illumination unit is the *candela* (cd), which is a source that emits monochromatic radiation of frequency 540 x 10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian. It is equal (approximately) to 60 candlepower in the old measurement system. The common *lumen* (lm) is a measurement of flux based on 1 cd at the point source. Light bulbs are rated in lumens. One watt is equal to 17 lumens, thus a 100 watt light bulb is rated at 1700 lms. However, the real consideration for anyone dealing with flags and the colors one sees is the *Law of Inverse Squares* as applied to intensity; i.e., Intensity = $1/(d^2)$, where Intensity in lumens is inversely proportional to the distance (d) from the object squared. See Fundamentals of Applied Physics by Olivo and Olivo

3 - THE AMERICAN PEOPLE'S ENCYCLOPEDIA, p8-314/315

4 - Fechner, Gustav Theodor (1801-1887): German philosopher and founder psychophysics. As a physicist he devoted himself largely to the study of optics and electricity. As a result of extensive experiment he formulated the principle that sensation increases in arithmetical progression to increases of geometrical progression in the corresponding stimulus. Also see FECHNER, GUSTAV THEODOR, American People's Encyclopedia, p8-422

5 - A typical lighted office or outdoors during daylight.

6 - The actual number of monochromatic (one color) frequencies is much less that the total number of colors the eye can resolve. This is because when two or more colors fall on the eye simultaneously and in congruity the sum of the two colors is seen. Thus when monochrome red and monochrome green are added they form yellow. When red and blue are added they form magenta, and blue and green for cyan. This is well know to those trained in the field of color television broadcasting; the only three colors in a television set are red, blue and green. However, a television set (or computer monitor) deals with light, and electromagnetic waves add in the eye by vector addition. So why doesn't this happen when one mixes paint? When an artist mixes paint the color produced is as a result of subtraction, since the

sensed color is a reflection, and thus reversed in phase, of the light falling upon the painting. A simple experiment will prove the point: mix red, blue, and green light and a white light results. Mix red, blue, and green paint, and you'll (in theory) get black (or a browish gunk).

7 - American States are notorious for slapping their seals on a "flag blue" field and being done with it. The results range from bad to horrendous. A few States, such as Texas and New Mexico, are exceptions, having well designed and immediately recognizable flags.