

How Do We Create Color Qualia in Our Mind's Eye?

How do we form the subjective perceptions of color (i.e. color [qualia](#)) in our mind? When photons of light from the visible spectrum of electromagnetic radiation hit the retina of our eye, cascades of neurons fire in our brain that send channels of information to the visual cortex. The visual cortex, in turn, converts that information into perceptions of color. How does the visual cortex form these perceptions, i.e. when the visual cortex decides to display the color “red” how does the subjective perception of “red” arise in our mind's eye?

One possible answer to this question involves the following aspects of biological brain activity:

- [Polar Color System \(PCS\)](#)
- [Homochirality](#)
- [Chiral-Induced Spin Selectivity \(CISS\)](#)
- [ElectroMagnetic \(EM\) Conscious Field Theory \(CFT\)](#)

Polar Color System

The Polar Color System (PCS) model represents mentally perceived colors as points residing on the three-dimensional surface of a [four-dimensional hypersphere](#). PCS is similar to the [Munsell Color System](#) (MCS) and the [Natural Color System](#) (NCS), both of which are based on Ewald Hering's [opponent process](#) hypothesis of color vision. MCS and PCS represent colors as objects in a three-dimensional space. In MCS, colors are represented as a central column of neutral shades from White to Neutral Gray to Black, surrounded by a cylinder of colored “hues” that is anchored on four sides by two sets of “opponent” colors -- Yellow-Blue and Red-Green (Figure 1). The NCS system is similar to MCS, but more modern, and more calibrated to actual human color perception.

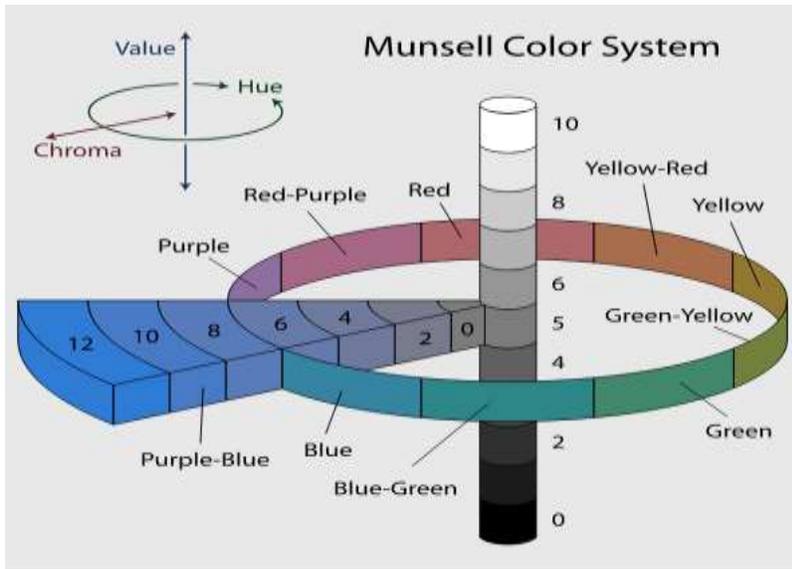


Figure 1 - Munsell Color System, collected from Wikipedia, https://en.wikipedia.org/wiki/Munsell_color_system

PCS modifies MCS and NCS by moving the central column of neutral gray colors onto the surface of a hemisphere, as shown in Figure 2. In addition, Figure 2 shows the distribution of the opponent colors Yellow-Blue, along with mixtures of Yellow and Blue with White, Neutral Gray and Black. The location of any specific color point on the hemisphere is then defined in PCS by the polar coordinate angles φ_1 and φ_2 .

So on the PCS hemisphere, pure White is located at $(\varphi_1, \varphi_2) = (90^\circ, 0^\circ)$. Pure Black is located at $(90^\circ, 180^\circ)$ or $(90^\circ, -180^\circ)$. φ_2 for Neutral Gray (N) is arbitrary, so it is denoted with *. Intermediate light gray colors between Neutral (N) and White are located at $(\varphi_1, 0^\circ)$, where φ_1 ranges from 0° at N to 90° at W. Intermediate dark gray colors between Neutral (N) and Black are located at $(\varphi_1, 180^\circ)$, where φ_1 ranges from 0° at N to 90° at S. For example, light-gray with lightness half-way between Neutral and White is located at $(45^\circ, 0^\circ)$.

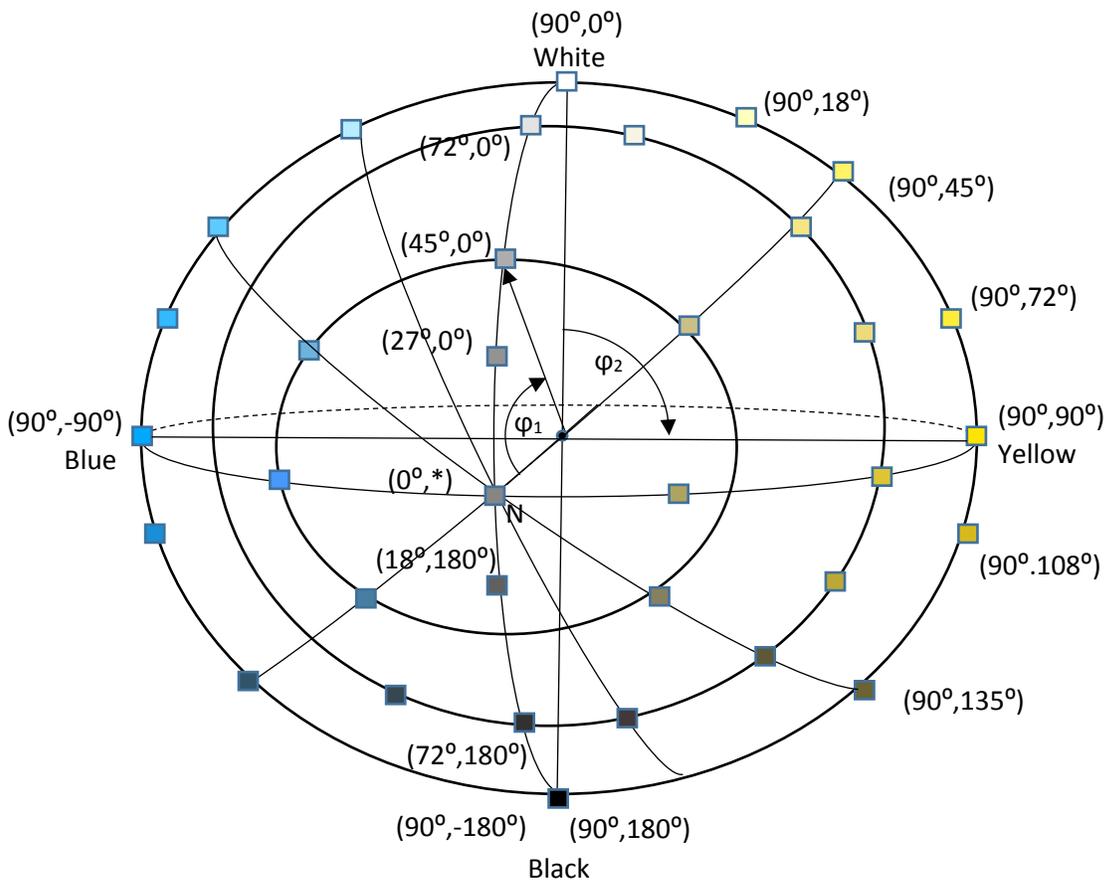


Figure 2 - PCS Color System - Blue-Yellow Hemisphere

The Red-Green opponent colors are added to the PCS hemisphere by adding a third dimension that is orthogonal to both the White-N-Black and Yellow-N-Blue half-circles and centered at N. Values for Red-Green hues are defined by adding a third polar coordinate φ_3 that is defined as the degrees of separation from Yellow. So $\varphi_3=0^\circ$ at Yellow, $\varphi_3=90^\circ$ at Red, $\varphi_3=180^\circ$ at Blue, and $\varphi_3=-90^\circ$ at Green.

Unfortunately, when a third dimension is added to the PCS hemisphere surface, the surface extends into four dimensions, so it can't be shown in totality directly on the page. However, different portions of the hemisphere can be shown successively in multiple figures, in order to help visualize the full surface. For example, Figure 3 shows a portion of the surface without White and Black, and without angle φ_2 .

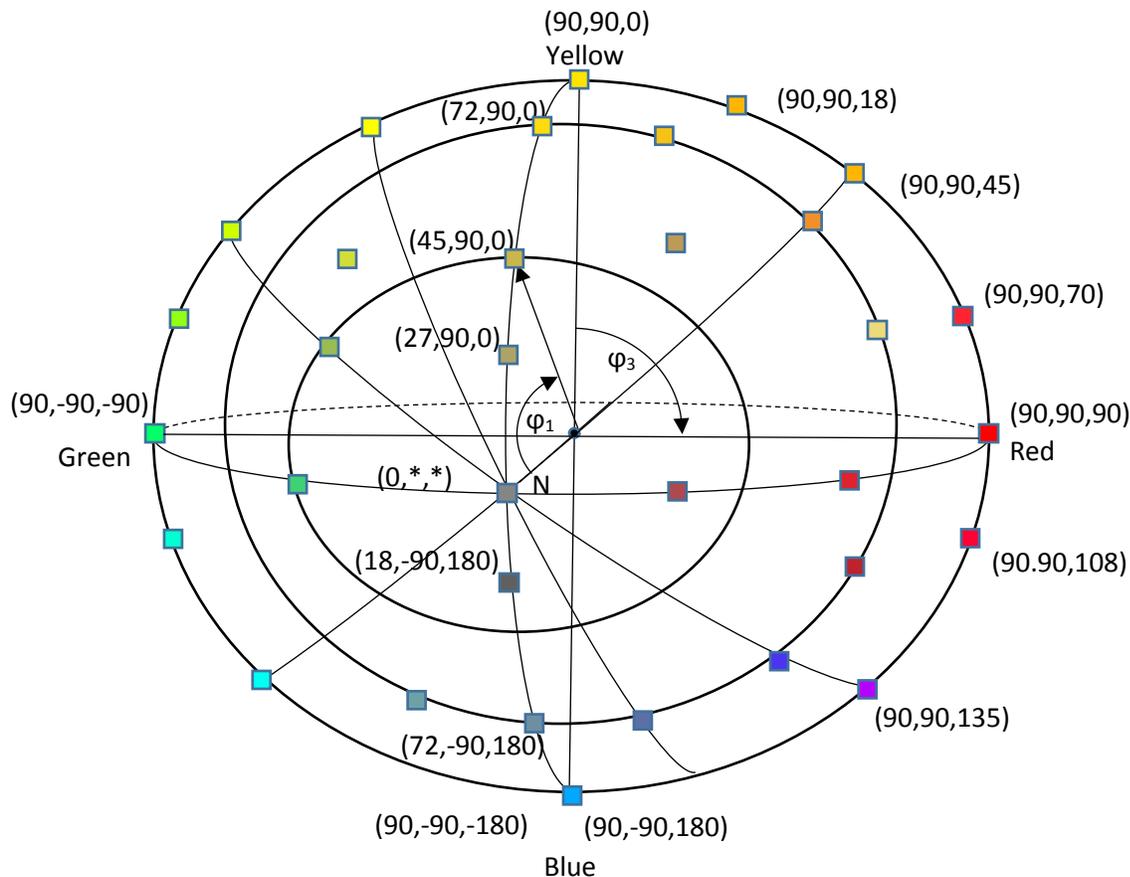


Figure 3 - PCS Yellow-Red-Blue-Green Hemisphere (w/o White-Black)

The spherical nature of PCS provides a natural explanation for how color qualia information might be sent to the brain's visual cortex. This is because a single point source can be used to deliver a spherical distribution of colors that become available to a receiver. Consider a dance floor rotating disco ball. That disco ball is a small object whose two-dimensional surface can transmit a spherical distribution of lights and colors into a large three-dimensional room. This idea can be extended up into four dimensions, in which a small four-dimensional "disco ball" could transmit colors in a spherical distribution consistent with the three-dimensional surface of a PCS hemisphere.

So how might a point object, or small microscopic spherical object, give rise to a spherical distribution of color qualia in the visual cortex? That explanation is given in the next three sections on Homochirality, CISS and CFT.

Homochirality

Chirality is an asymmetry in an object in which the geometry of the object cannot be superimposed on its own mirror image. For example, a human hand is a chiral object. The mirror image of a right hand is a left hand, which cannot be superimposed on the right hand. (That's why a right-handed glove won't fit on a left hand.)

A chiral molecule is an asymmetric molecule whose molecular structure cannot be superimposed on its own mirror image. Similar to human hands, chiral molecules are either left-handed or right-handed. Biological molecules are typically chiral, and large biological molecules made up of chains of chiral building-block molecules are always "homochiral", i.e. their chains contain either 100% left-handed or 100% right-handed molecules. For example, amino acids in biological cells are always 100% left-handed, and carbohydrates in cells are always 100% right-handed.

In contrast, non-biological mixtures that contain chiral molecules are almost always "[racemic](#)", i.e. they contain equal amounts of right-handed and left-handed molecules. It is not known exactly how homochirality emerged in the origin of life. However, because of the enormous entropic costs required to build and maintain homochirality, it appears that it must be [essential for the existence of life](#), as discussed in the next section.

Chiral Induced Spin Selectivity (CISS)

Homochiral molecules within living cells are capable of acting as spin filters that can select and synchronize the spin of the electrons streaming through them. This spin synchronization leads to quantum coherence of the electrons, which greatly increases the transmission yield and efficiency of the electron flow. This increased yield and flow allows living cells to function with much lower input energy requirements and waste heat production than any non-biological system. For example, a supercomputer that matched the processing speed and functionality of a 10-watt human brain would require enough [energy to power a building](#).

CISS is what allows living cells to manage and operate an astronomical amount of coordinated biological processes with limited amounts of energy extracted from the sun and the environment, and without overheating and burning themselves up with excess waste heat. Synthetic chemist James Tour gives an interesting explanation of the biological requirements for homochirality and CISS in [Episode 11](#) of his lecture series on “Abiogenesis: Origin of Life.”

Conscious Field Theory (CFT)

Chiral-Induced Spin Selectivity in living cells leads to [Quantum Coherence](#), [Quantum Entanglement](#), and [Quantum Criticality](#) within the cells. Within brain cells, these quantum effects lead to [Quantum Consciousness](#). There are many exciting areas of research being conducted today in Quantum Consciousness. One of these areas that applies to color perception is [Conscious Field Theory \(CFT\)](#).

In CFT theory, neurons in the brain generate synchronous coherent patterns in an ElectroMagnetic (EM) field. Multiple neurons provide input that is integrated into a single EM field. A component of this EM field is then transmitted back to other neurons to form a single subjective experience of consciousness. The integrated, coherent nature of the EM field is what allows the conscious mind to process and analyze multiple factors simultaneously from a complex set of information, e.g. the visual information from a human face.

The conscious experiences of color qualia are produced when color information from the retina are resolved into color hue selections within the visual cortex. When a color is selected based on the brain’s processing of the visual information from a particular region of the retina, multiple neurons fire synchronously to configure that color information onto the appropriate pixel within the mental image portion of the EM field. Because of the integrated nature of the EM field, the colors of every pixel of the mental image are experienced simultaneously by the consciousness, which itself then simultaneously causes multiple output neurons to fire. That’s why we are able to view and react to the entire visual field, say of a pure blue sky, as a single conscious experience.

The way that multiple pixels of the brain's mental image are configured to produce a single image may suggest an analogy to the way that a television screen's pixels are "painted" onto a TV screen. One difference, though, is that a TV paints its screen pixels one-at-a-time, sequentially, in a "[raster scan](#)" pattern across and down the screen. In contrast, the brain uses massively parallel processing to simultaneously code the full set of millions of mental pixels in the visual EM field many times each second.

But what causes the actual subjective qualia of "red" or "blue" to appear in our mind's eye? PCS theory proposes that the EM field is inherently "colorized", i.e. that the EM field has a color property that is manifested based on a color orientation. Apparently, when EM particles like electrons are somehow oriented, or "polarized", in a single "direction", then the EM field that they produce exhibits a certain color hue. Perhaps the hue is emitted from the EM field in that direction, or perhaps the field acts as a window into a colorized dimensional background that shows through it.

The colorized hues of the EM field are not actually "seen" visually by the conscious mind. Instead the conscious mind directly experiences the "redness" or "blueness" of the EM field, since the EM field defines the conscious mind itself. The visual field portion of consciousness actually "becomes" red or blue, or it becomes "one" with redness and blueness, as the brain is integrated with the EM field. Then, as with other parts of the conscious EM field, the colorized features of the internal visual field cause other neurons to fire, thereby enabling the color consciousness itself to act as a causal agent for subsequent mental processing.

So when I experience the sight of a deep blue sky, my brain configures the orientation of the visual portion of its EM field so that it turns blue, and I experience that blueness directly. When I view the beautiful colors of a [Notre Dame stained glass window](#), my brain configures the pixels of its EM visual field to act like millions of microscopic prom dance disco balls that actually fill my mind's eye with a kaleidoscope of colors. When my Dad looked at my Mother with a glint in his eye and conceived me – no, wait – that's something different.

PCS Color Dimensions

The spherical symmetries of the PCS system integrate naturally with the proposed EM colorized orientations. This is because spherical symmetries naturally occur when elementary particles interact within spatial dimensions. But how do the three color dimensions of PCS relate to the spatial dimensions of our Universe?

Since the PCS model space is a three-dimensional surface of a four-dimensional hypersphere, and since our Universe appears to be a [three-dimensional surface of space that is expanding into a fourth dimension](#), it is tempting to assign the three PCS dimensions to the three spatial dimensions of our Universe. Indeed, we could imagine the Neutral (N) apex of the PCS hemisphere as being oriented in the direction of the universal expansion. The three PCS dimensions then become the normal three dimensions of space that we experience every day.

But this is likely not the case. The reason is because our personal physical orientation is not fixed within the three spatial dimensions. We move around and orient our brains physically in any of these directions. It is difficult to think of a process in the brain that could manage three color dimensions whose orientations are constantly moving and changing relative to the brain's position.

Instead, it is more likely that the three PCS color dimensions correspond to three higher physical dimensions of space, i.e. higher dimensions as proposed by [string theory](#). These higher dimensions are active at the elementary particle level, but are unaffected by our physical movements in our normal three-dimensional space. In this scenario, our brains could be configured to convert visual information from the retina into colorized orientations of EM particles within the fixed reference frames of these three higher color dimensions.

The use of higher physical dimensions also gives the PCS model flexibility in case it needs to add extra dimensions, e.g. in the case of [tetrachromacy](#) or other higher levels of color vision. The higher dimensions also make it possible to extend the PCS model to explain sensory perceptions other than color vision, as discussed below.

Color Blindness and Enhanced Color Acuity

For some applications, PCS agrees in principle with MCS/NCS. Since PCS, like MCS/NCS, is based on the color opponency hypothesis, it explains [color blindness](#) in a similar manner. [Monochromacy](#) (total color blindness) in humans happens when a defect in the retina's cones or rods causes only a single channel of information to be sent to the brain's visual cortex to be converted into color perception. In this situation, the brain is forced to use a single dimension of the color system. In the MCS/NCS systems, the logical choice is the White-Black dimension, since the White-Black column is central to the system. In PCS, the White-Black dimension is only one of many dimensions symmetrically positioned around the color hemisphere, so its selection is arbitrary. This means that if PCS is closer to reality, then some monochromatic people's brains may choose dimensions other than White-Black for their "Black-and-White" experience.

In human [dichromacy](#), two channels of color information get passed to the visual cortex. In this situation, the brains of most people choose to use the White-Black and Yellow-Blue dimensions of the color system. Thus, their perception of Red-Green is reduced or eliminated.

Human [trichromacy](#) is the normal condition. Most humans send three channels of information to their visual cortex, which gives them the ability to perceive colors in all three of the PCS color space dimensions.

A (very) few people have [tetrachromacy](#), in which four channels of color information are sent to the visual cortex. Some fish, birds, insects and animals also have tetrachromatic vision. Tetrachromacy is said to be "four-dimensional", since four levels of information are used. But the four levels can still be specified with three dimensions of color perception. For example, the avian color space can be modeled as a [four-sided tetrahedron](#) in three dimensions.

The avian tetrahedral color space does have an increased color range into the ultra-violet, as compared to the normal human color space. This increased range could be incorporated into PCS by adding ultra-violet "hues" to the Blue-Yellow dimension, or by adding another dimension altogether if ultra-violet has its own opponent color.

Some birds and butterflies may have [pentachromatic](#) color vision, in which five channels of color information are sent to the visual cortex. [Mantis shrimp](#) can have up to sixteen channels of color information. These additional channels may provide increased color differentiation acuity, they may reduce the requirements for mental vision processing, and they may provide increased sensitivity to ultra-violet light and polarized light. But they don't appear to add more dimensions to the color space.

PCS Extensions

There is some evidence that the perceptual color space may involve more or different opponents than the standard Yellow-Blue and Red-Green. For example, [Pridmore \(2012\)](#) proposes three complementary colors Yellow-Blue, Red-Cyan and Green-Magenta. And, as we've mentioned before, avian color space indicates that the opponent pair Yellow-Blue may be extended into Yellow-UltraViolet. Any of these configurations can be incorporated into PCS by adding opponent color dimensions as required, and by modifying the color sequences within each dimension.

Another potential extension to PCS is to add other sensory qualia that are not limited to color vision. Along with vision, an [integrated qualia space](#) can also include hearing, smell, taste and touch (and perhaps several others). In an extended version of PCS theory, these additional qualia could correspond to inherent EM properties of additional higher physical dimensions of space. Then in this extension not only does the brain's EM field become colorized, but it also "sings" in one or more audio dimensions, smells and tastes in one or more olfactory dimensions, and aches or itches in a tactile dimension.

PCS provides an interesting potential explanation for why the extra compactified dimensions predicted by string theory are included in the overall geometry of our Universe. Along with requirements for mathematical consistency, these extra dimensions may provide the means necessary for essential sensory abilities to be available for use by advanced biological life.

Testing PCS

One test of PCS is that the hue distributions and mixtures on its color surface should correspond more closely to human perception than other color systems. For example, a perfect [Uniform Color Space](#) would be one in which the same geometrical distance anywhere within the space would reflect the same amount of perceived color distance.

Direct testing of PCS activities in the brain may become possible as Quantum Consciousness research progresses. Currently the conscious EM field hypothesized by CFT is too weak and localized inside the brain to be detected or manipulated by external instruments. If technology improves to the point where the conscious EM field can be detected or controlled within an experimental setting, then it may become possible to artificially invoke and control mental color qualia (and other sensory qualia) for testing purposes. Then the actual perceptual color space could be systematically mapped and analyzed, and compared to the PCS model and to others.