A Green Thought in a Green Shade

By C.L. Hardin

YELLOW SUN IN A BLUE SKY. GREEN LEAVES CARESSED BY THE WIND. Open the shutters of the eye, that window of the soul, and all such things are revealed. Nothing is more apparent than that things have colors, and that we have immediate perceptual access to those colors.

But are the colors that we suppose objects to possess the same as the colors to which we have such ready access? Physics describes the color-relevant properties of objects in such quantitative terms as 'surface spectral reflectance' and '580 nanometers.' These predicates capture features of objects that are fit to play a causal role. The colors of which we are perceptually aware, on the other hand, receive qualitative descriptors such as 'red' and 'chartreuse.' They are conspicuously absent in causal accounts.

We seem to have two domains here. Can they be joined? Can we establish a regular set of connections between, say, a particular spectral reflectance—or another complex of physical properties—and a particular perceived color, perhaps a sufficiently intimate connection to warrant our asserting that the perceived color is identical with that spectral reflectance or physical complex? The stock philosophical mantra for dealing with the problem is that an object has color C just in case the object looks C to a normal (or standard) observer under normal (or standard) conditions. Not so long ago, this seemed to be an unproblematic principle, and some philosophers still regard it as unproblematic. The tacit assumption was that the lighting condition is to be daylight and the observer one who is not color deficient.

But which daylight? Morning, noon, or afternoon? Sunlight or north daylight? And what shall we say about the colors on television sets or computer monitors? Is daylight the best way to judge them? The vaunted constancy of colors under various lighting conditions is really only approximate, and many artificial colorants are in fact highly

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inconstant with simple changes in illuminant. When a material looks to have different colors under different reasonable, or "normal," illuminants, how are we to determine which of the different color appearances corresponds to the "true" color of the object?

Our present concern, however, is not with the "normal conditions" clause of our philosophical mantra, but with the "normal observer" clause. Given a certain amount of variability among actual normal observers, a sensible move would be to take a statistical average of them and construct an official, artificial "Standard Observer." This is just what the Commission Internationale de l'Eclairage (CIE) did in 1931. Refined and improved upon over the years, the specifications that constitute the Standard Observer and its corresponding standard illuminants and standard viewing conditions have been invaluable for industrial applications. But their limits are well understood. First of all, to quote the authoritative handbook of Wyszecki and Stiles,

> The problem of specifying object-color perceptions has not yet been solved for the general case in which the observer views a complicated scene composed of a large variety of objects. Various visual phenomena, such as simultaneous contrast, successive contrast, color constancy, memory color, size, and shape of the objects, come into play and contribute significantly to the resultant color perception of the complicated scene; but the science of color has not advanced far enough to deal with this problem quantitatively.[1]

Secondly, the Standard Observer is silent about color appearance. From it we can learn when two samples will or will not seem to match in color for the Standard Observer, and, if they fail to match, we can gain an estimate of how different they are. But it will not tell us how a sample's hue changes as it becomes brighter, or dimmer, or more or less saturated. In an important respect, then, the Standard Observer fails to capture the *quality* of color. If the eye is the window of the soul, the Standard Observer doesn't do windows.

Finally, simply because it is a statistical construct, the Standard Observer will fail to capture individual variations in color matching, variations that are surprisingly extensive. Fifty-five years ago, Ralph Evans remarked,

> A rough estimate indicates that a perfect match by a perfect "average" observer would probably be unsatisfactory for something like 90 percent of all observers because variation between observers is very much greater than the smallest color differences which they can distinguish. Any observer whose variation from the standard was much greater than his ability to distinguish differences would be dissatisfied with the match.[2]

It is now possible to determine the extent of matching differences among normal observers and to gain some insight into the causes of the variation.[3] Using an instrument called the anomaloscope, a standard instrument for diagnosing color deficiencies, color-normal observers are asked to match an orange test hemifield with a mixture hemifield of red and green primaries in which the observer can set the red/green ratio. For men, the distribution of ratios is bimodal, falling into two distinct groups, with 60 percent of the observers in one group and 40 percent in the other. The distribution of ratios for women is unimodal, and broader than that for men. In the last decade it has been shown that these distributions are correlated with genetically based polymorphisms of longwave and middlewave cone photopigments. Here we have a clear case of quantifiable, biologically based individual variations in color perceptions for normal observers under rigorously controlled standard conditions. No scientific sense can be attached to the claim that some of the observers are perceiving the color of the stimulus correctly and others not.

The match that an observer makes between the two hemifields of an anomaloscope is a metameric match. The two sides have different spectra, but when the match is made, they look identical. Although metameric matches are rare in nature, they are very common in the modern world; the images of color photography and color television are metameric or approximately metameric matches to the color appearances of the objects that they represent. Because of inevitable variations in viewing conditions and in observers, such matches are to one degree or another problematic and rely on the large reservoir of forgiveness that the human brain has for color variation when the samples are not put side by side.

This issue is important in evaluating those philosophical theories of color that put colors outside the head. For example, Alex Byrne and David Hilbert[4] hold that surface colors are to be identified with classes of spectral reflectances that yield the same color appearance. Since they want to distinguish between the real and the apparent colors of objects, they need to establish a criterion for membership in a set of reflectances that are to count as the same real color. Because color appearances are a function of both viewing conditions and observers, they must establish normative conditions for both of these. I think that we are entitled to require that the choice of these conditions depend upon a set of reasonable principles. In the case of normal observers, whose color matches are to count as the correct matches; that is, which colors actually match and which colors only appear to match? I own a metameric slide rule, a device that has two sliding colored scales that may be independently adjusted. The observer moves the scales so that the portions of the two scales that can be seen through the window match to a close approximation. Change the illuminant, and the scales must be readjusted to yield a match. Keep the illuminant the same but change the observer, and quite often the match that satisfies the one normal observer will be seen by another normal observer as a gross mismatch. It will not surprise you to learn that when I adjusted the scales for a match that satisfied me, it failed to satisfy David Hilbert, and when he found a satisfactory match, I saw the colors of the scales as markedly different. My match was, of course, the correct one; Hilbert was the victim of a color illusion!

Actually, given my principles, I am as comfortable with Hilbert's match as I am with my own, but, given his principles, at least one of us must be wrong. But in that case, how would he proceed to decide the issue?

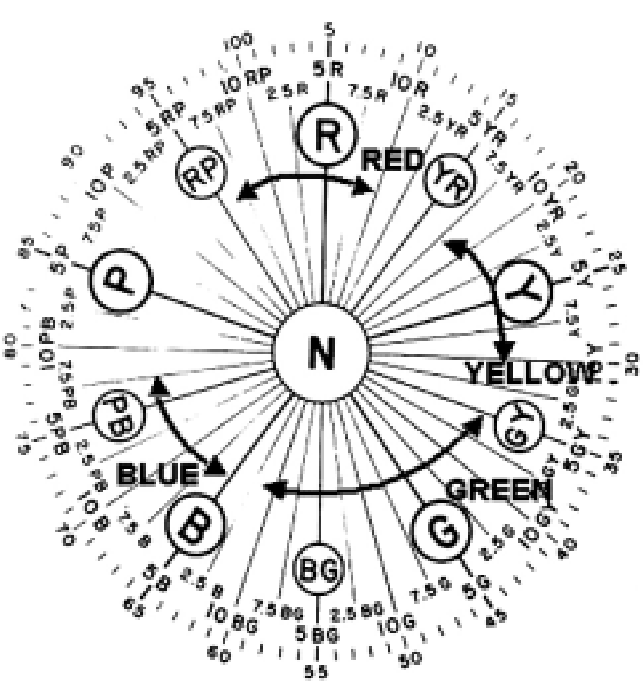
Color matching has to do with a judgement as to whether two color stimuli are seen as the same or as different. It does not tell us anything about the qualities of the colors that we experience; nor does it tell us into what categories they fall. It does not tell us whether the stimuli are red or blue, orange or brown; nor does it tell us why purples are more like red than like green. It is only by using our eyes that we can learn these things. If we wish to assign colors to stimuli, we must do so empirically, by discovering which sorts of stimuli bring about which sorts of color experiences. Given a particular observer in a particular state of adaptation and a particular set of observational conditions, there is a way to do this. The names of just four perceptually basic hues—red, yellow, green, and blue—are both necessary and sufficient to describe every hue.[5] The description of a hue is given in terms of its degree of resemblance to one pair of these basic hues. The four basic hues are called *unique* hues. A unique hue contains no perceptual traces of other hues. Thus, a unique green is a green that is neither yellowish nor bluish, a unique blue is a hue that is neither reddish nor greenish, and so on. By contrast, no purple can be a unique hue, since every purple is both reddish and bluish.

Vision scientists use two ways of determining what colors people see. One of them is to ask them to judge the degree of resemblance to unique hues. This is commonly called 'hue naming.' The other, the 'cancellation technique', requires them to adjust the amount of a light of fixed wavelength so as to cancel the component of a target light that is complementary to the light of fixed wavelength. Thus a fixed light seen by the subject to be a unique blue may be used to cancel the yellowish component of a target light, for example one that appears orange. When the cancellation is complete, the light that originally looked orange will appear to the observer be a desaturated red. Iterated across the spectrum, the cancellation technique will generate the opponent response function for the observer in question. Jack Werner and Billy Wooten showed that the average hue naming by observers is closely correlated with their opponent response as given by the cancellation technique.[6] Furthermore, the cancellation technique gives results that can also be calculated from color-matching data. So the color names that people give to stimuli are strongly, though indirectly, correlated to their execution of a behavioral task.

Since our old friend, the CIE Standard Observer, is a set of color-matching functions, we might now suppose that he might be pressed into service as a color categorizer. If so, we could use him to objectively classify all manner of surface spectral reflectances in terms of red, yellow, green, and blue. He would enable us to specify the unique hues and distinguish them from the binary hues. We could objectively determine classes of metamers.

Well, almost. But is almost good enough here? After all, the CIE Standard Observer is also known as the CIE Average Observer and, as such, is going to perform like some, but by no means all, real observers. As we have seen, real observers differ from each other in their color-matching and metameric classes, so it should come as no surprise that their opponent responses are different. Even small differences are of considerable significance for realist theories of color, for realists must shoulder the burden of deciding in a non-arbitrary fashion which normal observers are seeing colors as they really are and which ones are misperceiving them

In fact, the differences are large enough to be shocking, as we shall now see. The stimulus locus for a perception of unique hue has been studied with a variety of techniques for many years. Every study with a reasonably large number of observers has found a wide distribution of unique hue loci among normal perceivers. Because the studies have used different experimental protocols, the mean results do not agree well across experiments, but substantial variability among observers within any given study is a constant. It is generally accepted that more "naturalistic" experiments using surface colors will reduce the amount of variance from one observer to another, so I shall present you with the results of some unique hue experiments with colored Munsell papers that were recently done by Rolf Kuehni.[7] He used a 40-step hue set. The Munsell chips are approximately perceptually equispaced, so each chip is 1/40 of the hue circle. The figure shows the range of unique hue choices from experiments with two subject pools.



The male and female distributions are generally markedly different, and neither one approximates a Gaussian distribution for any of the hues. Even if the gender results are taken separately, no single chip will represent the unique hue choice of a majority of observers for a given hue category. The range of variability persists even when the choices of the least consistent observers are discarded. Furthermore, the unique hue choices of each individual are very stable over time.

There are approximately 10 distinct hue perceptions between two Munsell 40-Hue steps, so the unique red hue range of six steps works out to roughly 60 distinguishable hue differences. If the results for the four unique hue ranges are taken together, there fails to be consensus on 26 out of a total of the 40 chips composing the hue circle. Sixty percent of the hue circle is in dispute! We could arrive at a more conservative estimate by taking the results of a single set of experiments on the grounds that differences in the experimental protocols are likely to make for greater variability in outcomes. But even if we do this, there is no consensus on 16 of the 40 chips, a forty percent disagreement.

When the facts about the variability of color perception among normal observers are pointed out to defenders of color realism, one common response is that there may be disagreements about particular, determinate colors, but there is certainly agreement about determinable colors. We can all agree, for instance, that a particular object is red. Well, yes and no. It is true that all of the normal observers will call most of the chips in the unique red range 'red', most of the chips in the unique green range 'green,' and so on. But just how far does consensus go in color naming? Sturges and Whitfield[8] examined color naming of a large sample of the Munsell color solid with responses from 20 subjects. Less than 1/4 of the chips were named with both consistency and consensus. If we consider just the hue dimension, we notice that the ranges for the judgements of unique hues and the consensus judgements for the four basic colors correspond pretty closely. But the consensus colors form islands in a sea of non-consensual color naming. In particular, there is a pronounced gap in the hue range between the consensus green chips and the consensus blue chips that confirms the everyday observation that people commonly disagree about whether a particular color in this range is "really" green or "really" blue. So what is the determinable that covers this range? Grue? Actually, many languages lack separate basic color terms for green and blue, using an omnibus term to cover the whole blue-or-green range. There is, however, no known language with a basic term, that is, a term used with high consistency and consensus, that covers this intermediate region as 'orange' covers the hue region between red and yellow.

Should the realist content himself with the observation that all of us can agree that an object falling in this region is blue-or-green? The obvious rejoinder is that such an object falls under the determinables "bluish" and "greenish." This is perfectly true, but now we must ask whether we can generally agree of a given object whether or not it falls under a determinable such as "bluish." Take, for example, the Munsell chip 7.5G seen under the artificial daylight of Kuehni's second unique green experiment. Twenty-three observers judged it to be bluish, but 14 observers judged it to be neither bluish nor yellowish, and six observers saw it as yellowish. It seems that we cannot secure agreement on the extension of this determinable, though each particular person can determine that extension with a high degree of reliability. The argument can be repeated for each of the determinables red, yellow, and blue as well. But the extensions of these cover the entire hue space.

In the face of the facts of individual differences in color perception, realists such as Alex Byrne, David Hilbert, and Michael Tye take the position that some normal perceivers see colors as they are, whereas others perceive them erroneously. If the differences in perception were indeed small, we might be willing to keep them in the closet. But, as we have seen, the differences are simply too large for such a "don't ask, don't tell" policy. Not only must some substantial numbers of normal perceivers be significantly misperceiving, they must be chronically misperceiving. For his part, Michael Tye[9] is unfazed by this result. Perceptual errors of shape and temperature are common, says he, but we do not therefore suppose that shapes and temperatures are not features of the physical world. Our epistemic difficulties in determining the true colors of surfaces do not threaten the objective status of these colors.

So here's the part where that which has been given by one hand is taken away by the other. Much of the initial appeal of color realism was that colors seem to be presented directly to perception in all of their naked glory. Now, it appears that multitudes of us must content ourselves with knowing about colors indirectly. For us unfortunate souls, the veil of perception has been restored. Those of us who sometimes misperceive shapes and temperatures have recourse to instruments such as thermometers and rulers to correct ourselves, but we who misperceive unique green have no alternative ways of rectifying our false judgements. Byrne and Hilbert are prepared to accept this result, and cheerfully tell us that they are prepared to countenance "unknowable color facts."

Shades of Lord Kelvin! You will recall his pronouncement at the end of the nineteenth century that physics is essentially complete, there being but "two small clouds on the horizon," namely, the black-body problem and the negative result of the Michelson-Morley experiment. From these clouds quantum mechanics and relativity theory were to emerge. Defenders of the old order took refuge in unknowable facts about absolute velocity and determinate trajectories. Others, however, took the epistemological challenge to heart. They saw that a theory requiring unknowable facts is a theory that rests on questionable assumptions.

There is another brand of realism, notably advocated by Brian McLaughlin and Jonathan Cohen,[10] that has learned these lessons of modern physics. Its rallying cry is "Relativize!" Does the color that you see depend upon the illumination? Relativize! Does the color that you see depend upon the surround? Relativize! Does the color that you see depend upon your state of adaptation and the fact that it is your eyes that see it? Once again, relativize! A surface has a color K, not simpliciter, but rather with respect to conditions C and illuminant L for observer O under the state of adaptation A. Thus, every surface has as many colors as these parameters have values. Indeed, for every counterexample X, we need only add parameter X'.

Will this device work? It is difficult to see how it could fail to do so. Indeed, it will work all too well. To me, this woman's face is the very Form of Beauty incarnate. To Jonathan, it is a face that only a blind mother could love. Beauty is in the eye of the beholder, you say? No, it is an objective property of the woman's face, for I only need to relativize it to Larry's gaze, if only at time T. Ugliness is also an objective property of her face, provided of course we understand it as being relative to Jonathan's eye at time T. And so this same woman has the possibility of being all things to all men.

Beyond that, the plurality of color properties that the relativist generates is just too reminiscent (if I may use this word) of Gorgias' definition of virtue as related by Meno:

First of all, if it is manly virtue you are after, it is easy to see that the virtue of a man consists in managing the city's affairs capably, and so that he will help his friends and injure his foes while taking care to come to no harm himself. Or if you want a woman's virtue, that is easily described. She must be a good housewife, careful with her stores and obedient to her husband. Then there is another virtue for a child, male or female, and another for an old man, free or slave as you like; and a great many more kinds of virtue, so that no one need be at a loss to say what it is. For every act and every time of life, with reference to each separate function, there is a virtue for each one of us, and similarly, I should say, a vice.[11]

To which Socrates exclaims: "How fortunate I am, Meno! I wanted one virtue and I find that you have a whole swarm of virtues to offer." Here we have it: Must we choose between Byrne's cryptic colors and Cohen's chromatic swarm?

I think that we can avoid both. Let us look at what we can agree upon. We agree that the colors that we see are typically caused by the spectral power distributions that affect our eyes. There are no mysteries here, and no ungainly pluralities either. We agree on the basic mechanisms within our brains that process, categorize, and transform these stimuli. The net result of the workings of these mechanisms is in plain view, although the detailed nature of the mechanisms is something of which we are largely, though not entirely, ignorant. It is those mechanisms rather than the stimuli on which they operate that give unity and simplicity to the colors of experience. We also agree that the objects of chromatic seeing are not colored mental items, variously called "sensations" or "sense-data".

Where we might not agree is that color experience is qualitative, and that the same qualitative character can be present in experience even in the absence of the usual external stimuli. As I understand them, some color realists such as Gilbert Harman have maintained that we are directly aware of object color and that all color experience is to be explicated in terms of propositions about the colors of objects along with the notion of intentionality. If successful, such a maneuver would rid us of the qualia problem. Because I find a physical object's having a color to be a problematic notion, I do not think that the problem of qualitative content can be avoided.

Very well. But if physical objects aren't colored, and there are no mental color bearers, just where does color reside? My response is that color properties don't reside anywhere, because we don't need to suppose that there are any. What we do need to suppose is that we experience surfaces and lights and volumes as colored, which means that we must have experiences of a qualitative character. Most realists not of Harman's persuasion will grant that our experiences do have qualitative character. Just how that character is realized by our neural wetware is of course a very difficult question. I do not think that it is by any means an unsolvable question, or a question that goes beyond the resources of the science of the future, but it is in any event a question with which realists must also deal. My point is simply that since our world has both spectral power distributions and primate nervous systems, it doesn't also need colors.

The seventeenth-century poet Andrew Marvell,[12] having decided that he had neither world enough nor time, gave up pursuing his coy mistress and found solace in gardening:

When we have run our passion's heat,
Love hither makes his best retreat.
The gods, that mortal beauty chase,
Still in a tree did end their race:
Apollo hunted Daphne so,
Only that she might laurel grow;
And Pan did after Syrinx speed,
Not as a nymph, but for a reed.

And then came his insight into the nature of color:

Meanwhile the mind, from pleasure less,
Withdraws into its happiness;
The mind, that ocean where each kind
Does straight its own resemblance find,
Yet it creates, transcending these,
Far other worlds, and other seas;
Annihilating all that's made
To a green thought in a green shade.

I owe it to my colleagues in the Department of Textual Studies to deconstruct these last two lines. What is to be annihilated is of course the world of color properties, fabricated or "made" by color realists, with green serving as surrogate for all of the colors. "Thought" must be understood in the omnibus Cartesian sense, as covering all mental happenings; in this instance, "thought" means "visual perception". To call a thought, which we have now glossed as "perception," green, is permissible poetic license; the literal meaning of the phrase is "a perception as of green" or, better yet, "a perceiving greenly." "In" can only be understood in the constitutive sense, and the "a" in "a green shade" should be understood as a free variable, ranging over the shades of green.

This exegesis does not measure up to the elevated scholarly standards of Textual Studies, but I believe that Marvell, as a metaphysical poet, would have wanted a philosopher to make his thoughts more accessible to an audience of the twenty-first century. So here are the last lines of "The Garden," as amended:

> Annihilating all the false colors that realists have made
> To a perceiving greenly, as a constituent of each green shade.

You didn't expect philosophy to scan, did you? φ

Notes

[1] G. Wyszecki and W. S. Stiles, *Color Science: Concepts and Methods, Quantitative Data and Formulae*, second edition. (New York: John Wiley and Sons, 1982), 173.
[2] Evans, R. M., *An Introduction to Color* (New York: John Wiley and Sons, 1948), 196-7.
[3] See M. Neitz and J. Neitz, "Molecular Genetics and the Biological Basis of Color Vision," in W. G. K. Backhaus, R. Kliegl, and J. S. Werner (eds.), *Colour Vision: Perspectives from Different Disciplines* (Berlin: Walter de Gruyter, 1998), 101-119.
[4] A. Byrne and D. Hilbert, "Color Realism and Color Science," *Behavioral and Brain Sciences* 26 (1) (2003), 3-21.
[5] C. S. Sternheim and R. M. Boynton, "Uniqueness of Perceived Hues Investigated with a Continuous Judgmental Technique," *Journal of Experimental Psychology* 72 (5), (1966), 770-776.
[6] J. S. Werner and B. S. Wooten, "Opponent Chromatic Mechanisms: Relation to Photopigments and Hue Naming," *Journal of the Optical Society of America* 69 (1979), 422-434.
[7] R. G. Kuehni, "Determination of Unique Hues Using Munsell Color Chips," *Color Research and Application* 26 (2001), 61-66. Also see "Variability in Perception of Color Stimuli by Color-normal Humans" on Kuehni's web page, www.4nscu.edu/~rgkuehni Also see M. A. Webster et al., "Variations in Normal Color Vision. II. Unique Hues." *Journal of the Optical Society of America A* 2 (9) (2000), 1545-1555.
[8] J. Sturgis and T. W. A. Whitfield, "Locating Basic Colours in the Munsell Space," *Color Research and Application* 20 (6) (1995): 364-376.
[9] M. Tye, *Consciousness, Color, and Content* (Cambridge, MA: MIT Press, 2000).
[10] B. McLaughlin, "The Place of Color in Nature," in R. Mausfeld and D. Heyer (eds.) *Colour: Connecting the Mind to the Physical World* (Oxford: Oxford University Press, 2003), 475-505.
J. Cohen, "Color: A Functionalist Proposal," *Philosophical Studies* 113 (1) (2003), 1-42.
[11] Plato, *Meno*. 71E. Translated by W. K. C. Guthrie.
[12] Andrew Marvell, 1621-1678. The poems from which the quotations are taken are "To His Coy Mistress" and "The Garden."