nonzero at some visible wavelengths. Thus, to calculate the formula $\mathbf{r}(\lambda) + E(\lambda)/I(\lambda)$, we would have to divide by zero for any wavelength λ at which there is emission but no external illumination. And in cases in which the emission stays constant while the external illumination goes to zero at every visible wavelength, the productance values go to infinity at the wavelengths of emission. Suffice it to note that it is hard to see how this notion of productance value could be sensibly interpreted so that the color of a surface emitting light in the total absence, or near total absence, of external illumination could be identified as a type of productance.

2. The phenomenal structure of colors. As B&H point out, color physicalism must be squared with the perceived similarity relationships among the hues, and with the fact that hues, as we perceive them, admit of a unique/binary distinction. For this reason, they introduce the notion of a hue magnitude, telling us that there are four such magnitudes: **R**, **Y**, **G**, and **B**. According to their proposal, when an object looks unique red, it is represented as having 100% of **R**. And when an object looks purple, it is represented as having "**R** and **B** in a similar proportion, say a 55 percent proportion of **R** and a 45 percent proportion of **B**" (target article, sect. 3.2.1, para. 8).

For hue magnitudes to do the intended work, they must be physical properties of surfaces. To locate the hue magnitudes among such properties, B&H appeal to L-intensities, M-intensities, and S-intensities of color signals. The L-intensity of a color signal is the degree to which it would stimulate the L-cones; M- and S- intensities are interpreted analogously. They tell us that: "an object has some value of **R** if and only if, under an equal energy illuminant, it would reflect light with a greater L-intensity than M-intensity – the greater the difference, the higher the value of **R**" (sect. 3.2.3, last para.)

B&H tell us that LMS-intensities can be derived from color signals and cone sensitivities. The natural suggestion here is that LMS-intensities can be so derived by taking the product of the color signal and the cone sensitivity functions.[1] But then their theory makes mistaken predictions. On any of the standard procedures for estimating the S-, M-, and L-cone excitations for unique red surfaces, $S < (L + M)$, contrary to B&H's prediction that $S = (L + M)$.[2] This is because human color processing is such that the $S = (L + M)$ equilibrium points of the LMS space fail to map onto the blue-yellow equilibrium points of "phenomenal" color space – the color space generated by color-discriminations or multidimensional scaling data (Izmailov & Sokolov 1991; Jameson, forthcoming; MacLeod & Boynton 1979; Maloney 1999; Wuerger et al. 1995).[3] The same objection applies to the case of unique greens and achromatic grays; for the latter, the B&H proposal mistakenly predicts that $S = (L + M)$. Note, moreover, that many purplish surfaces excite the S-cones less than the L- and M-cones together.

3. Variation in normal color vision. As B&H note, on any of the standard criteria for normality, there is widespread variation in how surfaces would look in determinate color to normal perceivers in normal circumstances; and there is, as well, considerable variation in how they would look in various determinable colors.[4] Given this widespread variation, B&H are prepared to maintain that there is widespread color illusion among normal perceivers in normal circumstances.

This position is not forced on them by their adherence to color physicalism. It is open to a color physicalist to maintain that a physical property is a color only relative to a type of perceiver and type of circumstance of visual observation.[5] Thus, for instance, a color physicalist could hold that a physical property P is unique green *for* one type of perceiver in one type of circumstance, and bluish-green *for* another type of perceiver in that same type of circumstance. (Compare the fact that something can be digestible for one type of digestive system but not for another.) So when the surface looks unique green to the one type of perceiver in the circumstance in question and bluish-green to the other, neither perceiver is misperceiving the color of the surface. Color physicalists need not be color absolutists.

But B&H embrace color absolutism. They claim that color is like shape with respect to independence of experience. As they acknowledge, however, there are independent tests for determining whether a normal perceiver is misperceiving the shape of a surface, but in the case of color, "there is no such test" (sect. 3.4).

Given the fact that there is considerable variation in normal color vision as concerns unique green and the very serious possibility that there will be no independent test, B&H tell us that they are "prepared to countenance 'unknowable color facts' – that a certain chip is unique green, for instance" (target article, note 50). In so countenancing this, they are committed to countenancing that we cannot know what physical property unique green is. Moreover, for the same reason, they should be prepared to countenance that it is unknowable what physical properties the determinate colors are.

Given the lack of widespread variations as concerns red, blue, green, and yellow, B&H may think that, mere philosophical skepticism aside, there is no reason to doubt that we can know what physical properties red, blue, green, and yellow are. But it is hard to see why counting heads matters. As B&H note, the distribution of two L-cone photopigment variants varies significantly between males and females. Suppose that, as a result, a surface that would look some color C to the majority of normal color perceivers would look some other color C* to a minority (where neither C nor C* is a determinable of the other). The situation could be reversed through selective breeding.

As B&H correctly note, "physicalism about color is compatible with practically any view about the nature of mind" (sect. 3.5, para. 6). We believe, however, that it is their commitment to a particular theory of mind, a brand of representationalism, that leads them to color absolutism. They embrace the twofold view that the phenomenal character of a color experience supervenes on the content of the experience, and that the content of a color experience includes a color as a component. Commitment to color physicalism is, we believe, itself a reason to reject this brand of representationalism.

NOTES

1. The estimation of L-cone excitation is the product of the color signal and the L-cone sensitivity function, integrated over the 400–700 nm interval, and similarly for M- and S-cone excitations.

2. In addition, the difference between S and $(L + M)$ is substantial.

3. See especially Figure 2 in McLeod & Boynton (1979). The $b = (r + g)$ points (i.e., the $S = (L + M)$ points) in the square-shaped McLeod-Boynton chromaticity diagram constitute the top horizontal edge of the diagram, and only the violet end of spectrum loci fall near there. Reds fall near the bottom right corner of the diagram.

4. Here we use "determinate color" and "determinable color" as these terms are defined by Byrne & Hilbert.

5. See McLaughlin (2000; 2002; 2003) for a defense of this relativist brand of color physicalism.

Olive green or chestnut brown?

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Abstract: Reflectance and spectral power functions are poor predictors of color experiences. Only in completely relativized conditions (single observer, non-metameric set of stimuli, and single set of viewing conditions) is the relationship close. Variation in reflectance of Munsell chips experienced by color-normal observers as having a unique green hue encompasses approximately sixty percent of the complete range of hues falling under the category "green"; and in recent determinations of unique hues, ranges of yellow and green as well as green and blue unique hues overlap.

Among the many empirical facts of color experiences is the following: Unless seen in fully relativized conditions (in regard to color-normal observer, isomeric stimuli, and surround), specific visual spectral energy signatures can be experienced as many dif-

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ferent colors. For example: Objects having flat spectral reflectances from near zero to 100 percent can be seen as anywhere from black via intermediate grays to white and to light emitting; they can also result in noticeably chromatic experiences of any hue. Or, certain real objects with moderately complex reflectance functions can, when seen in the same surround, result, in one white light, in a distinctly greenish color experience (olive green), whereas in another white light, there could be a distinctly reddish experience (chestnut brown), and so forth. Given the empirical fact that in a complete *Ganzfeld* (where there is no opportunity for contrast against eyelids, nose, etc.) color experiences caused by given lights disappear rapidly, the case can be made that there are no colors without contrast. With contrast present, the color of a given field depends more or less strongly on the contrasting additional fields and surrounds. (The distinction between related and unrelated colors is only a matter of the type of contrasting field.) Empirically, then, objects and lights do not result in constant or near-constant color experiences, except, again, in a fully relativized set of conditions. No such condition can be specified as standard.

Depending on the observer and the conditions of viewing, given spectral energy signatures will result in color experiences that can fall into multiple color categories. This makes it impossible to define reflectance types unambiguously. In addition, there is the problem of defining color categories: They can be defined roughly, as say green, and then encompass a considerable number of hue subcategories and related variations in intensity and lightness (for object colors). Among the subcategories for green, the only one that can psychologically be defined with little ambiguity for a given observer is the "unique green" hue (UG). There are no similarly well-defined guideposts for other greenish perceptual hue experiences (encompassing an estimated 60 just-noticeably different green object color hue steps.)

How much does reflectance of a color chip need to differ for color normal observers to see it (in given conditions of lighting and surround) as having UG hue? A complete hue circle of Munsell color chips at constant chroma and lightness has 40 chips. Of these, when viewed against an achromatic surround, some 18 contain greenness. In World Color Survey results of populations with a full complement of Hering categories, the "green" category (at value 6 and chroma 8) typically encompasses 12 Munsell chips (MacLaury 1997). In experiments to determine individual unique hues using the same kind of Munsell chips, for color-normal observers, UG is experimentally found to encompass a hue range of about 7 chips, that is, approximately 60% of the complete average hue range of "green" (Kuehni 2001 and unpublished results). Any given chip (or given reflectance) of this group is seen by 60% to over 90% of the observers as not having UG hue. And these are results where observation conditions have not been varied. Analysis of additional six sets of more recent unique hue data indicates overlaps of yellow and green ranges as well as of green and blue ranges; that is, one person's unique yellow can be another person's unique green, and comparably for green and blue.

Byrne & Hilbert (B&H) are laboring in their attempt to come up with something akin to "reflectance type" for colors caused by light as is, or after passing through a transmission filter of some sort. Light sources cannot be considered to have reflection. (What is the reflectance of the sun, and does it differ at noon and at sunset?) How can the concept of *productance* be applied to a grating onto which white light falls? For transmitting filters, reflectance plays no role, except as specular (colorless in case of white light) reflectance, and all color experience involving the filter is a result of transmitted light arriving at the eye. The authors have not succeeded in establishing a uniform concept for all three cases (reflected, transmitted, emitted) and, as they agree, the effect of light source on the color experienced from viewing an object is damaging to their case.

B&H invoke Hering's theory (but without naming him) to describe the phenomenal structure of color. This does not help, because there is (at least as yet) no unambiguous relationship between Hering primaries and cone responses. It is widely accepted that, for example, subtracted cone responses $L - M$ have no immediate relationship to unique hues, and the scientific community is still in the dark as to what is the cause of unique hue perceptions.

To make the case that colors are in the outer world, B&H must (among other things) make a clearer case for reflectance types, one that does not allow a given reflectance to fall into different reflectance types. They must explain why spectral power signatures coming to the eye should be treated differently, in regard to resulting color experience, whether they are reflected from an object, transmitted, or simply emitted (i.e., why tristimulus values cannot be the vaunted reflectance types in all cases).

Our color response is obviously triggered, in extremely relativized conditions quite reliably so, by the spectral energy signatures absorbed by the cones. Are the resulting color experiences reconstructed or just constructed? A large amount of empirical evidence makes it much more likely that color is a construction of the brain, and not a reconstruction of the world by the brain.

Hue magnitudes and Revelation

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Abstract: Revelation, the thesis that the full intrinsic nature of colors is revealed to us by color experiences, is false in Byrne & Hilbert's (B&H's) view, but in an interesting and nonobvious way. I show what would make Revelation true, given B&H's account of colors, and then show why that situation fails to obtain, and why that is interesting.

Color physicalists like Byrne & Hilbert (B&H) generally reject Revelation, the thesis that the full intrinsic nature of colors is revealed to us in perceptual experience. Johnston (1992), following Russell (1912), supports Revelation and goes so far as to claim that any account that fails to render Revelation true, fails to be an account of the colors. For Johnston, though science can tell us much about how color perception works, there is nothing for science to tell us about the nature of colors that experience does not reveal. B&H are at pains to show that experience is not *inconsistent* with reflectance physicalism, but they do not say whether the content of perceptual experience tells us all that there is to know about colors. It doesn't, but given their account, that answer is not obvious.

Being committed to Revelation does not *eo ipso* commit one to rejecting reflectance physicalism. If colors are large sets of surface reflectances, Revelation is true just in case perceptual experience reveals to us the full intrinsic nature of these sets of surface reflectances. What would it be for experience to do this? Would it, for example, need to go so far as to tell us that colors are sets of *reflectances,* that is, sets of sets of reflectance magnitudes for each frequency in the visible spectrum? That seems a bit too demanding, since perception would then have to reveal the nature of photons, their wavelengths and frequencies, and so on. A more modest (and reasonable) claim is that Revelation is true if the personal-level content of an experience makes evident all of the respects in which a given shade of color is intrinsically related to all of the other shades of color.

In B&H's picture, experience represents hue in terms of hue magnitudes, which are dimensions along which determinate hues are intrinsically related to one another. The question then becomes: Do the relations between hues along the hue magnitude dimensions, **RG** and **BY**, constitute *all* of the ways in which determinate hues are intrinsically related to one another? If so, then Revelation is true of the hues, if not, then what are the intrinsic relations between the hues to which we lack perceptual access?

What it is to be a determinate hue, red_{29}, is to have a certain

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