Intrinsic colors – and what it is like to see them[1]

Zoltán Jakab

NSERC postdoctoral fellow, Rutgers University

In this brief commentary, I shall defend two related points, one about colors, the other about color appearances.

Maloney defines intrinsic color in two non-equivalent ways, first in terms of photoreceptor excitations, and second as a kind of reflectance property. As we shall see, the definition in terms of photoreceptor excitations (eq. 4 on p. 11 [IN THE DRAFT I HAVE]) faces more than one problem. Maloney's definition of intrinsic colors as reflectance properties that correspond to the linear-models-weights representation of surface reflectances fares much better, though, as we shall see, it faces problems of its own.

Consider the first proposal. Photoreceptor excitations are not intrinsic properties (here meaning *local properties*; *properties that are not relations to perceivers*) of distal surfaces, nor do they represent any such property. Instead, photoreceptor excitations represent *sensor quantum catches* (Maloney and Wandell, 1986, p. 29). Sensor quantum catches are not intrinsic but perceiver-dependent properties of perceived objects. The reason is that sensor quantum catches require the existence of perceivers. Were there no perceivers, there would be no sensor quantum catches. Color objectivism is the view that the existence of object colors does not depend on the existence of perceivers. So a color objectivist cannot maintain that object colors are sensor quantum catches, on pain of

[1] In Mausfeld R., and Heyer, D. (Eds.): *Colour Perception: Mind and the Physical World*. Oxford: Oxford University Press, 303-306.

inconsistency. Thus, this first proposal is incompatible with Maloney's espoused color objectivism.

The proposal faces additional problems. First, even if we keep the illuminant constant as Maloney suggests on p. 11 [IN THE DRAFT] we can only do so on arbitrary grounds, for there are many different illuminants that we might equally well choose as the reference illuminant. Second, on this proposal, intrinsic color depends on photoreceptor sensitivity profiles[2], and such profiles are known to substantially vary from one trichromat human to another (Lutze et al., 1990; Neitz and Neitz, 1998; Hardin, 1988, 76-82, and Fig. II-5A-B on p. 77). So even if we were to decide, for mathematical purposes, to keep them constant, the *intrinsic color* of any particular object in any particular fixed circumstance (reference illuminant, surround, etc.) will vary between normal trichromat human perceivers (Kuehni, 2001; Jakab, 2001; see also Block, 1999).

To summarize, if intrinsic color is identified with photoreceptor excitations, then intrinsic color depends on properties of observers in such a way that particular colors cannot be specified without mentioning some characteristics of observers (i.e., their photoreceptor excitations), nor can they be physically instantiated in the absence of observers. Since, intuitively, intrinsic colors should be local properties of the distal objects of perception, this is a controversial result.

The second proposal for intrinsic color (representation of surface reflectances by linear models: basis functions and weights: p. 13 IN THE DRAFT) fares better. The idea here is that the basis functions of linear models mirror some fundamental, universal

[2] For this reason it is not correct to say that the Λ_ε matrix depends only on the unknown illuminant (p. 13 [IN THE DRAFT]). It does also depend on photoreceptor sensitivities (e.g., Wandell, 1995, p. 307, eq. 9.12) and this too makes a difference to intrinsic color (according to the notion under evaluation).

reflectance characteristics of terrestrial surfaces.[3] These fundamental reflectance characteristics in turn derive from some general physical and chemical properties of those surfaces (Maloney, 1986, pp. 1677-1678). Color vision represents particular reflectances by linear combinations of a small set of basis functions. If we identify intrinsic colors with the fundamental reflectance characteristics that human color vision is sensitive to, we avoid the above controversy about perceiver dependence. Notice, however, that individual differences in color perception still introduce a problem for this approach. For if, as a matter of fact, one and the same surface in the same circumstances can look one color to one normal observer and another color to another, then that surface cannot have an *absolute* color, only a relative one. However, as McLaughlin's analysis shows (this volume), even though colors have to be perceiver-relative, they can still be intrinsic, that is, perceiver-independent properties of surfaces. One and the same surface reflectance is one color for one observer (in one circumstance, etc.), and another color for another observer (in another circumstance). Still, (1) we can specify particular colors in terms that do not make reference to any parameter of observers (e.g., redness := *surface reflectance such-and-such*), and (2) correspondingly, particular colors remain instantiated in the absence of observers. Neither of the latter two conditions is satisfied if color is thought to be photoreceptor excitation.

On both conceptions offered by Maloney, intrinsic colors depend, for their identity, on properties of, or relations to, observers. This is because individual differences in color perception make the notion of absolute color untenable (see McLaughlin, this

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[3] One such characteristic is that reflectance is a smooth, slowly varying function of wavelength (Maloney, 1986; Westland and Thomson, 1999). This is not to say that there exists an unambiguous one-to-one correspondence between a determinate list of reflectance characteristics and any particular selection of linear model basis functions. As I understand it, that is not in fact the case.

volume). This looks like a retreat of some sort since, intuitively, intrinsic colors are supposed not to depend on properties of (or relations to) observers; they are supposed to depend only on local properties of the distal object of perception – that's what 'intrinsic' is meant to emphasize. This notion of intrinsic color falls with color absolutism. Still, Maloney's second conception is compatible with a modified notion of intrinsic color: criteria (1) and (2). For, as McLaughlin (this volume) has argued, color objectivism does not require color absolutism.

Let us turn to the distinction between colors and color appearances. In another paper, Maloney (1999, pp. 409-414) discusses how the linear models framework relates to the opponent processing model of color perception. Briefly, the idea is that, following Stiles (1961, p. 264; Maloney, 1999, p. 410), for purposes of theoretical analysis color vision can be divided into two very general stages: (i) adaptational states of the pathways of chromatic processing, and (ii) the processes that adjust and modify these adaptational states. Color processing consists of a number of transformations of retinal signals including multiplicative scaling, additive shifts, and opponent recombination. The outcome of all these transformations is color appearance. These transformations contain certain parameters (coefficients for multiplicative scaling, constants for additive shift and so on) that are systematically modified by some characteristics of visual stimulation. The general schema is, transformations on receptor inputs at a given retinal location are influenced by previous retinal input and simultaneous input at other parts of the retina. This information about retinal surround determines the parameters for transformation of the cone signals at the retinal point under consideration. Now, the linear-models-based algorithms of surface reflectance estimation figure in adaptational control: they are *part* of the transformations by which color appearance is reached from retinal input (Maloney, 1999, p. 413). The first transformation of photoreceptor excitations is their multiplication by the lighting matrix $\Lambda_{\varepsilon}^{-1}$ (p. 13 IN THE DRAFT; see also Maloney, 1999, p. 413; Wandell, 1995, p. 307). The lighting matrix is illumination-dependent, and this transformation has the function of discounting the effect of illuminant changes, thereby achieving (approximate) color constancy. The result of this transformation is the visual representation of surface reflectance by linear-models weights. This representation then undergoes a further transformation that determines color appearance. This further transformation (function F in Maloney, 1999, p. 413) is arbitrary in the sense that, in principle, some species with trichromat color vision and photoreceptors of the same kind as ours could discriminate the same reflectance types as trichromat humans can, form the same linear-models-weights representations of them, yet still apply some different F function (second-site multiplicative attenuation, opponent recombination: Maloney, 1999, p. 410) to them so that despite the fact that such organisms discriminate the same reflectance ranges by their color experiences as we do, their color space (unique-binary division, similarity metrics) would be substantially different from ours. As Maloney says (1999, p. 413), in principle any one-to-one transformation of the linear-models-weights representation would equally well serve to determine color appearance; constraints on this transformation should come from further assumptions about how this second stage of color processing operates in humans. That is, particularities of surface reflectance estimation by color vision do not alone determine color appearance. Color appearance crucially depends on further transformations in the visual system that are independent of information about surface reflectance, but play a key role in shaping our color space.

This observation is extremely relevant to the evaluation of so-called representational externalist theories of color experience (Dretske, 1995 and Tye 1995, 2000). Dretske and Tye claim, in effect, that the phenomenal character of color experience (roughly the same as color appearance) is straightforwardly determined by information about surface reflectance represented in color vision. Colors, in their view, are types of surface reflectances. Moreover, the representational content of color perceptions arises from the information that these perceptions carry about colors[4], and the phenomenal character of color experiences is the same as their color content. Object color figures as the key component in color content, and color content just is color phenomenology: this means that object colors crucially determine what it is like to see them, i.e., the phenomenal characters of color experiences. Dretske's and Tye's views thus constitute the most straightforward denial of Lockean secondary quality theories.

However, as we have seen, Maloney's model has the consequence that intrinsic colors (surface reflectances) do not determine what it is like to see them. Therefore, if his general approach to color vision is right, then representational externalism about color phenomenology is wrong, and some internalist approach to phenomenal color experience has to be correct. (Internalism is the view that the phenomenal character of color experiences – that is, what it is like to see colors – is determined by what happens in the nervous system.[5]) Finally, note that nothing in what I have said questions the idea that color experience reliably tracks types of surface reflectance.[6]

[4] Tye endorses a non-teleological notion of content that is very close to Fodor's account (Fodor, 1990). For Fodor, content is essentially the same as information. Dretske's notion of content is teleological, still it is very close to that of information (see Dretske, 1981, 1988; McLaughlin, this volume).

[5] For a defense of internalism, see McLaughlin 2002. My inclination is to side with McLaughlin (and Maloney) regarding the determinants of color experience, and break out of Atherton's dilemma (this volume) by saying that Revelation simply is a mistaken intuition that is far from being untouchable by scientific development. Just as science once taught us that our intuitive views about intrinsic inclination to

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fall were plain wrong (i.e., a *rather* unreasonable way of thinking about free fall), it now is teaching us that the idea of Revelation is wrong in much the same way. Therefore we *are* entitled to separate colors from what it is like to see them.

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