Color realism redux

Authors' Response

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Abstract: Our reply is in three parts. The first part concerns some foundational issues in the debate about color realism. The second part addresses the many objections to the version of physicalism about color ("productance physicalism") defended in the target article. The third part discusses the leading alternative approaches and theories endorsed by the commentators.

Our target article had three aims: (a) to explain clearly the structure of the debate about color realism; (b) to introduce an interdisciplinary audience to the way philosophers have thought about the issue; and (c) to argue that colors are certain sorts of physical properties ("productances").

R1. Foundational issues

R1.1. The problem of color realism

Although most of the commentators appear to accept the way we frame the debate about color realism and agree that the issue is important, some do not. **Teller** clearly explains why she thinks that the debate is "an uninteresting terminological dispute," and **Warren** and **Reeves** seem to be of the same opinion. Visual science, according to Teller, is concerned with the regularities that obtain between three kinds of entity: visual stimuli (e.g., tomatoes and their properties), neural states (e.g., such-and-such activation in V1), and conscious perceptual states (e.g., a visual experience as of a red tomato).

In **Teller**'s view, once the regularities between stimuli, neural states, and perceptual states have been accounted for, there is nothing left to explain. In particular, there can't be any interesting issue about the nature of colors, or about whether visual stimuli are colored. In one way of using "red," as standing for the properties of visual stimuli that cause certain color experiences, obviously tomatoes are red. In another way, as standing for "a conscious perceptual state," tomatoes are not red. The color realist, Teller thinks, is simply insisting on the first terminological usage; to claim that this is an important issue is "just confusing and counterproductive."

We conjecture that the reason **Teller** sees only a tedious squabble about words is that she fails to recognize fully the *intentionality,* or representational nature, of visual experience (see, in particular, the commentaries by **Jackson** and **Van Gulick**). If color experiences are "mere sensations," capable of being identified by their "qualitative feel" rather than in terms of what they represent, then Teller's position is perfectly understandable. Once we have accounted for the "regularities" between external stimuli and color experiences, it is hard to see why there would be a further question about whether color experiences represent the world as it really is. Color experiences are caused by such-and-such external stimuli, and in that rather uninteresting sense may be said to represent those stimuli, as smoke may be said to represent fire, but that is all.

However, vision science does in practice have a richer notion of visual experience. In addition to finding the mechanisms that underlie and produce regularities of the sort **Teller** describes, vision scientists theorize about the information these mechanisms supply to other stages of processing. Consider some visual illusions: say, the Zöllner illusion, the Hermann grid illusion, or a case of apparent motion. When vision science tries to explain such illusions, the task is not solely to account for the "regularities" between the stimuli (parallel lines obliquely crossed with shorter lines; a grid of black squares on a white background; flashing lights) and certain sorts of "visual sensations." In the case of illusions, part of what is to be explained is why, in these circumstances, the visual system makes an *error;* that is, why it conveys to the perceiver the *misinformation* that the lines aren't parallel, that there are some gray spots on the white background, that the lights are moving. In **Funt**'s terminology, an explanation is sought for why the visual system fails to "estimate" accurately various properties of the distal stimulus. Sometimes, for example, the explanation of visual illusions appeals to some "real-world assumption" of the visual system (say, that the illuminant is above the perceiver). These explanations presuppose that the visual system is estimating stimulus properties. And if it is, we can ask exactly which properties are being estimated. That is all we are doing in the case of color.

We emphasized that the problem of color realism is "primarily a problem in the theory of perception, not a problem in the theory of thought or language" (target article, sect. 1.1). **Maund** complains that this is a "false dichotomy." He thinks that because the properties of interest are picked out by English words like "red" and "green " (as we of course admit), this shows that the problem of color realism is fundamentally about "our ordinary concept of color." (Notice that this sort of argument would show that an inquiry into *anything* – black holes, life on Mars, dinosaurs, and so on – is fundamentally an investigation into the relevant concepts.) However, Maund seems to be assuming a description theory of reference. That is, he is assuming that the word "red" refers to a certain property because speakers associate a certain descriptive condition with "red" (for example, the property that causes such-and-such visual sensations). On this view, armchair "conceptual analysis" will tell us what that condition is, and color science will tell us whether there is any property of tomatoes that meets the condition. If there is such a property, then it is the property of redness and tomatoes are red. If there is no such property, then tomatoes aren't red. Maund is in good company (see, in particular, Jackson 1998), but for familiar reasons (Kripke 1980; Soames 2002) we reject his assumption (see also the discussion of **Jackson**'s commentary below). No amount of conceptual analysis, we think, is going to provide a substantial descriptive condition that, together with the relevant empirical facts, will allow us to identify redness with, say, a type of reflectance. (In this connection, Maund briefly alludes to the distinction, much discussed recently by philosophers, between *conceptual* and *nonconceptual* content. There are different ways of understanding this distinction [Byrne 2003b], and we are not sure which one Maund has in mind, but at any rate it seems to us not to be particularly relevant to the present issue.)

MacLennan's interesting discussion of Ancient Greek color terminology nicely illustrates why it is a mistake to focus the color realism debate on concepts expressed by ordinary color words. The words may well carry lots of semantic baggage that is not relevant to an investigation into the properties represented by our visual systems.

Maund has a reasonable concern about our brisk early dismissal of sense-data (sect. 1.3.1), and we concede the issue deserves more discussion (for a recent useful treatment, see Smith 2002), although it would be out of place to pursue the matter here.

Saunders has some fundamental disagreements with us (and, clearly, most of the other commentators). One of her main complaints is that we "reify" reflectance, and by this terminology (see Quine 1953) she simply means that we hold that reflectances exist. Saunders's reason for saying this is a mistake is that reflectances "lack crucial invariances," by which she apparently means (see van Fraassen 2001, pp. 156–57) that there is no agreement between observers about the reflectances of objects. Since colorimetry obviously shows that this is false, it is not a very good reason. Saunders refers approvingly to van Fraassen's (2001) alleged claim that reflectances are "public hallucinations," but this is a complete misreading: van Fraassen's point is about rainbows, mirages, reflections on water, and the like, not reflectances.

R1.2. Intentionality

Jackson is sympathetic with both our physicalism and representationism, but he thinks that there is a problem about the representational content of color experience that we fail to address. The problem can be formulated as the following reductio ad absurdum argument: (1) Tomatoes look to have the property red. (2) Reflectance physicalism is true; specifically, the property red = reflectance type *R*. Hence: (3) Tomatoes seem to have *R*.

But this conclusion is incorrect: As **Matthen** puts it when presenting essentially the same argument, "it is obviously false that, simply on the basis of color experience, any proposition about reflectance becomes apparent to the (naïve) observer." The culprit must be either (1) or (2); (1) is plainly true, so (2) is false.

Matthen endorses this argument and concludes that colors are not reflectances. However, he does not explain why the argument is not a variant on the following philosophical chestnut: (1) Gottlob believes that the morning star (i.e., the heavenly body that rises in the morning) is visible; (2) the morning star = Venus, hence (3) Gottlob believes that Venus is visible. Since (1) is true and (3) is false (or so we may suppose), (2) is false: Venus is not the morning star. Because Matthen knows very well that this last argument is invalid, he must think that considerations peculiar to the color case prevent the standard diagnosis from applying to the first argument. But we are not sure why he thinks this.

Jackson's response to the first argument is to say that it fails for exactly the same reason as the second argument: basically, that one may represent *one* thing (say, the planet Venus) in *two* different ways (for example, as *the heavenly body that rises in the morning*, on the one hand, and as *Venus*, on the other). In fact, in Jackson's account, the parallel between the two arguments is exceptionally close. The property red is represented in our experience as the property that "plays such and such role," just as the planet Venus is represented by Gottlob's belief as the thing that "plays the role" of rising in the morning.

We agree with **Jackson** that to respond to the first argument, a color physicalist needs to spell out how colors are represented in experience. In fact, we already sketched the beginnings of an account that is a rival to the sort Jackson has in mind: Color experience represents objects as having proportions of hue magnitudes (sect. 3.2.1).

In **Jackson**'s proposal, the colors are represented as the occupiers of certain "roles." These roles are specified "topic neutrally" (Smart 1959), so as to explicitly allow for the possibility that physical properties might occupy the roles. If empirical science tells us that reflectance *R* occupies the redness role, then redness = *R*. In Jackson's view, this identity is contingent; as **Dedrick** explains, we hold that such an identity is necessary. In our account, color experience has no such topic neutral content. Therefore, unlike Jackson, we do not think that the conclusion that redness is such-and-such physical property is entailed by (1) a detailed specification of the content of color experience, and (2) various empirical facts about the physical properties of tomatoes and the like. By our lights, without a solution to the problem of "naturalizing semantics" we cannot clinch the case for physicalism (see sect. 2.6 of the target article). (In contrast, by Jackson's lights, the book on color physicalism can be closed without a naturalistically acceptable account of mental representation.)

Jackson agrees with our representationism about color experience, and its consequent rejection of the possibility of certain sorts of "inverted spectrum" scenarios. However, as **Kulvicki** helpfully points out, we (and Jackson, in fact) can accept the possibility of creatures that represent the colors very differently from ourselves. (**Van Gulick** rightly insists that this apparent possibility is genuine.) Relatedly, Kulvicki also notes that Revelation (Johnston 1992) fails in our account (which it also does in Jackson's).

In the target article, we expressed some skepticism about current attempts to reduce mental representation in physical or functional terms. We are not incorrigible skeptics – perhaps more progress could be made by taking **Van Gulick**'s point about the importance of "inner factors." In any case, **Pautz** thinks our skepticism was well-placed, and buttresses it with some serious argument. Pautz claims that this poses a problem for reflectance physicalism: According to him, we have to explain why visual representation can be reduced, or at least why the representation of colors can be. What we don't see, however, is why a plausible case can't be made for reflectance physicalism even without the assumption that there is a reductive account of mental representation; after all, the target article attempted to do exactly that.

R2. Objections to productance physicalism

R2.1. Productance

Most recent philosophical discussions of color physicalism have focused on attacking or defending the thesis that color is to be identified with reflectance (or some derivative thereof). And, in fact, almost all the issues concerning physicalism can be raised and settled, limiting discussion only to reflectance. (This is why – to answer **Dedrick**'s implicit question – "productance physicalism" appears only once in the target article. This Response also uses the terminology of "productance" sparingly.) In discussing the colors of light sources and filters, however, a generalization of reflectance, which we call "productance," is required (sect. 3.1.2). Colors, in our view, are anthropocentric productance-types (sect. 3.1.1) that – to a first approximation – are visually represented as proportions of "hue magnitudes" (sect. 3.2.1).

Kuehni misses the point that productance incorporates emission and transmission as well as reflection, and implies that we attempt to reduce emission and transmission to reflection. We establish a "uniform concept" by combining all three processes rather than reducing two of them to the third.

Dedrick thinks the main problem for our physicalist theory of color is that some nonreflectors appear colored, and he questions the motivation for our introduction of productance. The motivation is simply this: (1) light emitters, opaque reflectors, and transmitting filters are perceived as similar in color, and (2) it is plausible to think that these features are physical properties. We suspect Dedrick has missed the extent to which we are only supplying a name to previously recognized similarities among physical phenomena. We wouldn't presume to say whether productance, as defined by us, will be useful to vision scientists, but that there are important similarities among light emitters, transmitters, and reflectors is already a part of vision science.

Jakab & McLaughlin are troubled by productance being undefined relative to zero illumination. Although they mention this only in the context of a light emitter, the denominator in the definition of productance is zero whenever the illuminant is zero, no matter what the numerator might be. This mathematical artifact is also a feature of the common definition of reflectance as the ratio between the light reflected by a surface and the light incident on it; this is not a problem with the definition of reflectance and neither is it a problem with the definition of productance. Jakab & McLaughlin seem to think that according to our account, a firefly in total darkness has no productance and hence no color. We thought we had made it clear that our view has no such consequences; evidently we did not. To repeat, according to our account, productances are relative to illuminants but they are also independent of the actual illumination: Objects including light sources have (finite) productances in total darkness. Jakab & McLaughlin also find a problem with the fact that productance relative to illuminant I approaches infinity as I tends to zero, a concern shared by **Mausfeld & Niederée**. However, this is entirely unproblematic, and the ordinary definition of reflectance again illustrates why.

Note that instead of using the terminology of "reflectance," we could use "inverse reflectance" (1/reflectance). Speaking of inverse reflectance is obviously just another way of representing the same facts as speaking of reflectance, yet inverse reflectance approaches infinity as the amount of reflected light approaches zero. Of course, there may well be practical reasons to prefer the terminology of "reflectance" over that of "inverse reflectance"; likewise, there may be questions about the utility of "productance," but we are not suggesting that color scientists should start using this terminology.

Decock & van Brakel attempt to use the fact that productances are relative to illuminants to pose a dilemma. Representing the productance of a surface relative to illuminant I by the function $p(\lambda, I)$, they ask whether we identify the color of a surface with "the binary function $p(\lambda, I)$ with variable I, or with the simple function $p(\lambda, I_a)$ for a given illuminant I_a." We adopt the spirit, if not the letter, of their second horn. As mentioned earlier, we hold that colors are productance-types; an uncharacteristically simple example of a productance-type could be represented as the following set of productances: $[p_1(\lambda, I_a), p_2(\lambda, I_a), p_2(\lambda, I_b), p_3(\lambda, I_c)]$. (For a surface that does not emit light the illuminants can be ignored, because $p(\lambda, Ix) = p(\lambda, Iy) = r(\lambda)$, where $r(\lambda)$ is the reflectance function.) As Decock & van Brakel correctly point out, this has the consequence that surfaces have many colors – there is no such thing as "the" color of a surface. We do not understand why this is problematic.

Setting the alleged dilemma aside, **Decock & van Brakel** provide some examples that purportedly show the failure of productance as a complete account of color. When an orange laser beam is viewed sideways on, what one sees is (they imply) orange but, they say, on our theory "the object one is looking at is a cylinder of air," which is presumably not orange. We do not understand why Decock & van Brakel think that our theory implies that nothing orange is seen. In the situation described, one sees a cloud of dust particles that reflect the laser light (perhaps this is what is meant by a "cylinder of air"); these nonorange particles appear orange, and in that respect, one's experience is illusory. However, one also sees the orange light source (as one sees the sun on water, or the room lighting in a mirror), and in that respect one's experience is veridical. A similar description applies to Decock & van Brakel's example of a movie screen. They apparently think that the screen changes from white to multicolored when the show starts; we think that the screen's appearance is an illusion, but the appearance of the light source (seen because it is reflected from the screen) is – at least to a significant extent – veridical.

(On a related point, we do not deny, as **Mausfeld & Niederée** claim we must, that an experience of a white object under red illumination is "an experience of two colors at the same location"; we have claimed elsewhere – Byrne & Hilbert 1997a, note 15 – that such an experience represents both the color of the illuminant and the color of the object.)

R2.2. Metamerism

Metamerism is often thought to pose a special problem for physicalism about color. We respond to this difficulty by claiming that color vision delivers information about types of reflectance, not determinate reflectances (sect. 3.1.1). Two objects that match metamerically are, we say, represented as having the same reflectance-type. And if the objects do in fact have reflectances that fall within this reflectance-type, then they both possess the colors they appear to have. Some commentators contend that this response fails to accommodate the fact that metameric matches are very sensitive to changes in the illuminant – objects that appear the same in color under one illuminant can appear different in color under another similar illuminant. **Brill, Kuehni**, and **Mausfeld & Niederée** all ask how, given these facts about sensitivity, we define the relevant reflectance-types. They think we must somehow single out some illuminant as privileged, and define the reflectance-types that are the colors with respect to it. Since any such choice will be arbitrary, they conclude that there will be no independently motivated way of defining the visually represented reflectance-types, and hence that our view is mistaken. This problem is at root the same as the one posed by interobserver variation in color vision (see sect. 3.4 of the target article, and R2.6, below), that there is no principled way of picking out some perceivers as privileged. The problem is not in identifying when two objects are represented as having the same reflectance-type: That will be true whenever they look to have exactly the same color. Rather, the commentators are asking us to identify precisely *which* reflectance-types are represented by *which* color experiences. We admit we cannot do that (see sect. 2.6 of the target article) but insist that this does not prevent us from mounting a convincing argument for reflectance physicalism. It is worth emphasizing that none of our critics is any better off: For example, relativists (see R3.1, below) can do no better at identifying the properties represented by color experiences.

Hahn claims that we do define the colors in terms of privileged perceivers ("normal human trichromats") and privileged ("standard") conditions, but his main point does not depend on this misinterpretation. He uses the fact that metameric matches can easily be broken by changing the illuminant to urge on us the conclusion that any difference in reflectance that can be detected under some illuminant is a difference in color. Consequently, for Hahn the determinate colors are just the determinate reflectances, not reflectance-types. Although the target article focuses on the visually determinate colors, we observe (note 28) that we don't intend that our account conflict with the view that Hahn offers. In fact, one of us (Hilbert) has defended a similar view with a similar motivation (Hilbert 1987, pp. 83–87). There is no incompatibility between the claim that color vision only represents reflectance-types and the claim that every difference in reflectance is a difference in color.

R2.3. Hue magnitudes

To account for the perceived similarities between the colors and their opponent structure, we proposed that objects seen as colored are represented as having proportions of "hue magnitudes" (sect. 3.2.1; for a similar treatment, see Bradley & Tye 2001). This account allowed us to reply to various widely accepted objections to physicalism, notably **Hardin**'s (1993) charge that physicalism cannot account for the binary/unique distinction.

If this account and physicalism about color are correct, it follows that the hue magnitudes are themselves physical. We gave a rough indication of the sort of physical properties they are, in terms of relative cone responses (sect. 3.2.2). No doubt we should have emphasized more strongly that this was *not* any kind of definition of the hue magnitudes, even given the assumption of physicalism. (**Hardin** and **Jakab & McLaughlin** may well be under this misapprehension, for which they should not be blamed.) Whether an object has a certain value of a hue magnitude does not depend at all on human cone responses or even on whether any perceivers exist – hue magnitudes are simply certain reflectance types, and for that reason are perceiver-independent. **Kuehni**, **Jakab & McLaughlin**, and **Pautz** note that the relationship between cone responses and (perceived) unique hues is not at all straightforward, but this is no embarrassment; we were merely trying to illustrate our view using a very simple model, and to show how there is no obvious barrier to supposing that individual hue magnitudes are physical properties.

Pautz thinks that the magnitude proposal cannot account for the unique/binary distinction. His purported counterexamples apparently assume that we endorse the following schema ("B&H's formula"): property *P* is reddish-yellowish if everything that is represented as having *P* is represented as having the hue magnitudes *R* and *Y* in roughly equal proportion. His first example is a hypothetical case where everything that looks circular seems to have [a roughly equal proportion of] *R* and *Y;* but, Pautz objects, "circularity . . . is not binary reddish-yellowish." However, we certainly do not endorse Pautz's schema. First, note that Pautz is evidently taking a phrase like "property *P* is reddish-yellowish" to mean that property P *has the property* of reddish-yellowishness, rather than to mean that property *P* *is identical to* the property of reddish-yellowishness (in philosophical terminology, the "is" is the "is" of predication, not the "is" of identity). But, according to us, *objects* like tangerines (or their surfaces) are reddish-yellowish, not properties; therefore we think that instances of the left-hand side of Pautz's schema are always false. (For more on this issue, see Byrne 2003a.) What we do endorse is this: The property orange (i.e., reddish-yellowishness) is identical to the property of having the hue magnitudes *R* and *Y* in roughly equal proportion. Once this is cleared up, Pautz's objection dissolves.

Pautz has another objection: that magnitudes can't be "extradermal physical properties" because, for example, an object's proportion of *R* might be twice its proportion of *Y*, whereas it makes no sense to speak of the "proportion" of a property, extradermal or otherwise. But this objection confuses how properties are represented with the properties themselves. It is rather like arguing that temperatures aren't properties on the grounds that while 4° Fahrenheit is twice 2° Fahrenheit, it makes no sense to say that one property is twice as great as another.

R2.4. Recovery of reflectance information

Both **Funt** and **Maloney**, in their very helpful commentaries, discuss the extent to which the visual system might recover object reflectances. They both take us to task for exaggerating the degree of color constancy characterizing human color vision. This may have been a defect in our presentation; we did not intend to give the impression that color constancy is "almost perfect" (Funt), and certainly not that it is "perfect" (Maloney).

Maloney thinks we are committed to perfect color constancy because he mistakenly attributes to us the view that the actual reflectance of a surface determines the color descriptors computed by the visual system. On the contrary, we admit errors in represented reflectance and hence mismatches between the estimated reflectance-type of the target surface and the reflectance-type of the surface itself (see sect. 3.4 of the target article, and R2.5, below). **Funt** emphasizes that the underlying mechanisms of color perception are subject to various kinds of error and variability, and we agree.

Both **Funt** and **Maloney** propose that a better version of our view would employ the distinction – to use Funt's terminology – between a surface's reflectance-type and the visual system's "estimate" of its reflectance-type. However, – perhaps due to the opacity or unfamiliarity of our philosophical jargon – they do not recognize that this very distinction features prominently in the target article. Our view that reflectance-types are represented in color experience is translated by Funt's terminology as the claim that the color vision system estimates certain reflectance-types. Although this estimation will often be inaccurate, Maloney's commentary raises the interesting possibility that in a range of certain naturally occurring environments it might be exceptionally good – although never perfect.

Funt also takes up some of our remarks about the CIE 1971 Standard Observer (sect. 3.1.1). We objected that tristimulus coordinates are not suitable to specify reflectance-types, partly on the ground that they are relative to an illuminant. Funt correctly points out that this objection does not run very deep; we welcome his suggestion that a perspicuous representation of reflectance-types could employ an amended version of the CIE system.

Reeves suggests that the spectral characteristics of the opponent systems can be explained by attunement to the phases of daylight and the necessity for decorrelating the cone signals. Whether this is right or not, we can be sure that the selective pressures driving the evolution of the primate visual system were surely complex; in any case, Reeves's claim is compatible with the visual system having the overall function of acquiring reflectance information (Shepard 1992). Reeves also claims that color constancy for human color vision is quite poor; however, see **Maloney**'s commentary for a different perspective (see also Brainard et al., in press; Kraft & Brainard 1999).

R2.5. Contrast and context

Suppose we are right in contending that color vision functions to extract information about reflectance from the visual stimulus. Nothing follows from this about which aspects of the stimulus are used to generate the visual system's estimate of reflectance-types. A multiplicity of scene features are of potential relevance to the task of estimating reflectance, and it is an open empirical question exactly which ones are used in which ways by the visual system. **Cornelissen et al.**, **Kuehni**, **Rudd**, and **Todovorić** imply that our account somehow neglects these facts. This is a mistake: Our claim that colors are reflectances does not imply that reflectance is the only causally important factor in color vision.

Color contrast effects are powerful and pervasive. Given complete control of the surround, a colored patch can be made to appear to have virtually any color. These facts suggest to **Decock & van Brakel** that it is more appropriate to think of the color as an object in relation to its surround, rather than as a reflectance-type (see also Clark 2000). However, they do not directly respond to our charge (sect. 3.1.3) that this confuses color with the conditions necessary for its perception. As Tye (2000, pp. 153–55) points out, there are also contrast effects for shape; yet this does not show that the shape of an object is a relation to its surround. In distinguishing between the properties color vision represents and the mechanisms by which color vision extracts information about these properties, we are not implying that the surround is a minor factor in color perception.

Hardin and **Todovorić** press the question of *which* surrounds reveal the true color of the target. This is just another instance of the demand for independent criterion of veridicality, which we reject (see sect. 2.6 of the target article and R2.2, above). It is also worth emphasizing **Rudd**'s observation that for complex scenes like those typically encountered in our visual lives, the perceived color of an area is relatively independent of scene composition (see also Whittle, in press).

R2.6. Variation

Imagine a type of animal whose sense organs detect a range of physical properties P_1, P_2, and so on. Its sense organs afford the animal a fairly accurate view of the distribution of these properties in its environment. However, – partly because the computational problem of recovering information about these properties from the stimulus array is underconstrained – mistakes are made. Frequently, the animal's sense organs will deliver the misinformation that an object has P_i, where the object in fact has a very similar property P_j. Further, because of natural variation between individual animals of this type, the following situation can arise. The same object appears to one individual to have P_i, and appears to another individual in the same circumstances to have a different but very similar property P_j. However, usually the difference between an object's having P_i, and its having P_j is of no ecological significance, so these sorts of minor misperceptions, and minor differences between individuals, have no adverse practical consequences.

Described in this abstract way, our imagined animal seems quite biologically plausible; indeed, one would expect this kind of situation to be ubiquitous. And, in our view of color perception, this kind of situation is ubiquitous – which seems to have provoked consternation and alarm among many commentators.

Our view does not, *pace* **Cornelissen et al.**, "[reduce] the idea, that objects are colored, to an untestable belief." To say that vision is our main source of evidence about which colors objects have is not to say that we do not have *enough* evidence. According to us, ordinary visual experience provides us with ample evidence that objects are colored, in particular, that tomatoes are red, and so forth. We were not as explicit as we could have been on this point. This is doubtless why **Jakab & McLaughlin** misinterpret us as saying that the reason, or a large part of the reason, for believing that tomatoes are red is that tomatoes look that way to the majority of perceivers. Their complaint that "it is hard to see why counting heads matters" is therefore misdirected.

However, the picture is complicated by determinate shades like unique green, about which there is substantial disagreement. Here we assumed that the fact of such disagreement would *undermine* an individual's perception-based reason to believe that a certain chip is unique green. Thus, as we said in note 50 of the target article, we are prepared to countenance "unknowable color facts" – concerning, for example, whether a particular chip is unique green.

Hardin thinks that our insouciance about "unknowable color facts" is "a damning admission" and compares our attitude to a dogmatic proponent of the electromagnetic ether who holds that the Michelson-Morley experiment shows merely that facts about the Earth's motion through the ether are unknowable. We do not think the analogy is apt. The ether hypothesis, in conjunction with some plausible auxiliary assumptions, predicts a non-null result in the Michelson-Morley experiment, which of course was not observed. Hardin's imagined ether enthusiast preserves his theory at the price of an *ad hoc* denial of the auxiliary assumptions. Notice that what is wrong with the ether theorist is not his invocation of unknowable facts, but his denial of the auxiliary assumptions. What is the parallel in the case of color realism? What is the prediction of the theory that is not borne out by experiment? Color realism predicts (in conjunction with some plausible auxiliary hypotheses) that some things are unique green. But here the parallel breaks down. It would be begging the question to insist that this prediction is incorrect. Rather, Hardin's argument at this point must simply be that if some things are unique green, they must be knowably so, which reduces his argument to the simple assertion that our position is unacceptable.

Averill describes some ingenious hypothetical cases of people whose color perceptions differ from our own (in particular, gold looks red to them), and claims that these possible cases show that, if reflectance physicalism is correct, no one knows whether anything is red. However, we agree with many contemporary epistemologists that remote "skeptical hypotheses" – for example, that Averill's hypothetical people, not ourselves, are right about the color of gold – do not need to be ruled out by some independent procedure for us to know that they do not obtain (e.g., Austin 1946; Goldman 1976). Averill protests that we do not take the epistemological concerns seriously enough. We agree that the epistemology of perception is a difficult business, but we deny that our view makes it especially hard to explain how we have access to colors. To the extent that there is a worry, it is just an instance of a more general problem, one that has nothing in particular to do with color, and still less with reflectance physicalism.

Cohen thinks that our Professor Plum analogy is flawed, because the background beliefs that support the conclusion that Plum was murdered by someone or other have no counterpart in Hardin's (1993) unique green example. We disagree. Imagine Hardin's Munsell chips arranged in a long line. Here are some background beliefs that, for all Cohen has shown, we are entitled to. First, the chips are all green. Second, those at the far left-hand end (say) are bluish-green and those at the far right-hand end are yellowish-green. Third, traversing the array from left to right, the chips get less bluish and more yellowish. It follows from these commonly agreed facts that the less distinguishable we make adjacent chips, the more likely it is that the array contains a chip that is neither bluish nor yellowish.

R2.7. Nonhuman color vision

We argue that there is no incompatibility between our version of physicalism and the thesis that many nonhuman animals have color vision. We do, however, claim that to possess color vision an organism must have the ability to extract information about reflectance from the visual stimulus. This understanding of what it is to have color vision is more restrictive than the one usually appealed to in the literature on comparative color vision. Organisms that are capable of discriminating between spectrally different, equiluminant stimuli possess color vision, according to the standard criterion. However, if they don't extract or represent reflectance information, then they lack color vision, according to us. **Dedrick** disparages this view as "cognitive imperialism." Here, we think, the dispute really is just about words. Suppose that color vision in human beings generates representations of reflectance-type and that in doing so it makes use of mechanisms that enable spectral discrimination. One terminological option would be to apply the term *color vision* to visual capacities that extract information about reflectances. Another would be to apply the term to capacities that make use of mechanisms that support spectral discrimination, regardless of whether they extract information about reflectances. We prefer the first option but have no serious complaint against those who prefer the second. Once the nature of the mechanisms and the information they make available has been described, there is no further substantive question about whether the organism really has color vision or not.

R3. Other approaches

R3.1. Relativism

As **Cornelissen et al.** point out, grass is food for a cow, but not food to us, because cows can digest grass and we can't. (See also **Jakab & McLaughlin** on digestibility.) Strictly speaking, nothing is *simply* food: The proper locution is "food for *X*," where "*X*" is replaced by the name of an organism (either a type or an individual). Similarly, nothing is *simply* soluble: Some things are soluble in water, others are soluble in alcohol, and so forth. In the jargon, *relativism* is true about food and solubility. There is no single property of *being food,* rather, there is a family of properties: food for cows, food for humans, food for Smith, food for Jones, and so forth. Some commentators, in particular **Cohen** and **Jakab & McLaughlin** defend *color* relativism (see also **Matthen**'s commentary; Cohen 2003; Jackson & Pargetter 1987; McLaughlin 2000; 2003). According to them, there is no single property of greenness: rather, there is a family of properties: green for perceiver P_1 in circumstance C_1, green for perceiver P_2 in circumstance C_2, and so forth.

Relativism can reconcile many apparent cases of disagreement. Smith says "Grass is food"; Jones says "Grass isn't food." Relativism (about food) allows that *both* may be right – if Smith means that grass is food for cows and Jones means that grass isn't food for humans, then there is no disagreement, and they both spoke truly. The basic motivation for relativism about color is that it promises to reconcile apparent cases of "perceptual disagreement," as in Hardin's example of unique green (see sect. 3.4 of the target article, and **Cohen**'s commentary). "Color absolutists" like ourselves describe such cases as follows: A certain chip looks unique green to Smith and bluish-green to Jones; since nothing can be both unique green and bluish-green (this is a further assumption, but one we grant), either Smith or Jones (or both) is misperceiving the chip's color. Color relativists have a different account: The chip looks unique green for Smith in C_S to Smith, and it looks bluish-green for Jones in C_J to Jones (where C_S and C_J are the relevant "type of circumstance of visual observation," in **Jakab & McLaughlin**'s phrase). Further, according to the relativist, the chip has *both* properties: It is unique green for Smith in C_S and bluish-green for Jones in C_J.

As **Jakab & McLaughlin** note, a color relativist can also be a color physicalist. So relativism offers the physicalist a solution to the problem of variation. Why don't we take it?

Because we think that widespread misperception of the determinate colors is not at all an unwelcome result, we do not think that a relativized version of physicalism has any advantage over our "absolutist" theory (as **Jakab & McLaughlin** call it). Relativism makes color illusions very rare (just how rare will depend on the details; the accounts offered by Cohen [2003] and McLaughlin [2003] differ in this respect). The near-infallibility of color vision is a result to be avoided, not embraced. Moreover, although relativism might appear attractive at first glance, in fact it suffers from serious problems.

One difficulty for relativism can be brought out by a simple example. Imagine that you have just eaten a tasty crimson fruit, and that you are now looking at another fruit of the same kind. (To avoid irrelevant distractions about color language, imagine you are an Old World monkey.) You recognize the fruit as having the same distinctive shade of red as the first, and that's why you reach for it.

Rather surprisingly, this simple explanation of your behavior is not available to the color relativist. Call the first "type of circumstance of visual observation" (**Jakab & McLaughlin**'s phrase) C_{F1}, and call the second C_{F2}. Unless the relativization to types of circumstances is to be pointless, the relativist must concede that the details of the example could be filled out so that C_{F1} and C_{F2} are *different*. We may assume, then, that $C_{F1} \neq C_{F2}$. According to the relativist, the color the first fruit appeared to have was what we can call "crimson for you in C_{F1}," and the color the second fruit appeared to have was "crimson for you in C_{F2}." Never mind how we should understand these unfamiliar expressions – the important point is that, because $C_{F1} \neq C_{F2}$, the expressions are supposed to pick out *different* properties (just as being soluble in water is a different property from being soluble in alcohol). According to the relativist, the first fruit seemed to you to have a *different* color than the second, and hence the relativist cannot endorse the simple and obvious explanation of your fruit-eating behavior. For this reason, among others, we reject relativism.

R3.2. Ecological and sensorimotor accounts

We can all agree that color vision is an evolved capacity possessed by a wide variety of types of animals occupying different environments and with different ecological requirements. **Ben-Ze'ev**, **Huettel et al.**, **MacLennan,** and **Myin** claim that this fact favors a Gibson-inspired "ecological" or "sensorimotor" account of color over the view we defend.

As **Clark**, **Funt**, **Huettel et al.**, **Maloney,** and **Myin** point out, recovery and processing of color information draws on many features of the scene (and the perceiver's relation to it) other than the reflectance of the target surface. One source of color information may well be changes in the proximal stimulus induced by the perceiver's motion through the environment, as suggested by Clark and Myin (see also Myin 2001; O'Regan & Noë 2001a; 2001b). However, as Clark evidently realizes (along with Funt and Maloney), none of these interesting and important proposals about *the sources organisms use to recover color information* is in any tension with the claim that *the information recovered* is about reflectances. Interpreted as a claim about what color vision tells us about the world, ecological and sensorimotor contingency accounts appear to conflate the sources of color information with color information itself. In any case, as Clark nicely demonstrates, one might use the genuine insights behind these accounts to support color physicalism, not to reject it.

MacLennan raises the issue, discussed in section 3.3 of the target article, of whether reflectances are insufficiently ecologically relevant to be identified with colors. As MacLennan says, reflectances derive their significance in the lives of animals from their correlation with other properties more directly connected with ecological needs. Many of the correlations that make reflectance information useful are, in addition, local and temporary. But although this shows that reflectances are rarely of primary ecological significance it does not begin to show that colors are not reflectances. On the contrary, this feature of reflectances is entirely welcome because color is rarely of primary ecological significance. Many of the correlations that make color information useful are also local and temporary and as a result many organisms adjust their responses to color cues on the basis of their past experience. (This is why we find **Huettel et al.**'s enthusiasm for the Gibsonian terminology of "affordance" misplaced. There is no single kind of behavior that the perception of a specific color affords.)

R3.3. Pluralistic realism

Matthen advertises "pluralistic realism," an interesting account of color that he has developed in a number of publications (1999; 2001; in press), and **Decock & van Brakel** profess a similar view. (Just how similar the two views are is questionable. The heady Quinean thesis of ontological relativity [Quine 1969] seems to be an important component of Decock & van Brakel's position, but it is no part of Matthen's view as we understand it.) One strand of pluralistic realism is that, although objects *are* colored, "there is no mind-independent property that all color perceivers track or detect, no one ecological problem that they all try to solve" (Matthen 1999, p. 84). Realist accounts like ours, which claim that all color perceivers (including nonhuman animals) detect reflectances (or productances), are not pluralistic in the intended sense. However, we agree with Matthen that color vision systems in different species are put to very different uses, and so despite our being "monistic" realists, we do not think there is a single ecological problem that all color vision systems try to solve.

Another strand of pluralistic realism is its commitment to relativism. According to **Matthen**, the tomato that I see as unique red and you don't, "really is unique red in my visual system's 'sense,' and really isn't in yours." As far as we can see, these two strands are entirely independent. At any rate, we reject the second strand for the reasons given in R3.1.

R3.4. Eliminativism

A number of our commentators hold that objects like tomatoes aren't colored and hence that creatures with color vision are all subject to a pervasive illusion: As **Kuehni** puts it, "color is a construction of the brain." The predominant motivation in the commentaries for eliminativism appears to be the fact of variation in color vision, which we dealt with in R2.5, above. However, **Rudd** and **Nijhawan** offer other arguments.

Rudd gives the following argument: "A surface having particular reflectance characteristics can . . . appear to have any one of a large number of colors. Thus, the claim that color can be identified in any simple way with a class of reflectances is wrong." But Rudd's conclusion does not follow from his premise. The one-many mapping between reflectance and apparent color only establishes the (unsurprising) fact that the *apparent* color of a surface cannot be identified with one of its reflectance-types, not that the *real* color of a surface cannot be identified with one of its reflectance-types.

Nijhawan is not just a *color* eliminativist; according to him, apparent *spatial* properties are not possessed by objects like tomatoes. We are not completely sure why he thinks this, but here is one perhaps revealing remark: "If . . . processes early in the visual pathway are considered, then the after-image case, the prism displacement case [where the location of a red disk is misperceived], and the 'normal' viewing case, are all similar. So, a theory of color perception needs to explain all of these situations." This suggests the following line of thought: Visual perceptions seem to depend only on "processes early in the visual pathway," and not on how things *are* in the scene before the eyes, so what we perceive must be in our "inner environment," not in our outer environment. And if we do not actually perceive things in our outer environment, we presumably do not have any reason for thinking that external objects are either colored or shaped. This is basically the notorious "argument from illusion" (see Austin 1962; Smith 2002).

Two general points about eliminativism are worth stressing. First, if eliminativism is correct, our perceptual apparatus, and that of many other animals, has evolved to represent a range of properties that nothing has (and maybe that nothing could have). Just how it could have done that is something of a mystery (for dissent on this point see Hardin 1990). Second, if eliminativism about color is plausible, the arguments for it can probably be adapted to show that other perceptual modalities are equally infested with error. If we are forced to conclude that nothing has any color, then sound, to take **Handel & Erickson**'s example, should be banished along with it. Eliminativism about color thus threatens to obliterate anything resembling our intuitive conception of a perceiver's environment, as populated with variously colored, noisy, smelly, and tasty objects.

The second point can be turned around. If realism about sound is plausible, realism about color is too. Moreover, as **Handel & Erickson** insightfully recognize (see also O'Callaghan 2002), physicalism about sound (and other perceptible qualities) to a large extent stands or falls with physicalism about color.

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Letters "a" and "r" appearing before authors' initials refer to target article and response, respectively.

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