Color Objectivism and Color Pluralism

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ABSTRACT

Numerous arguments exist against color objectivism, the view that colors exist independently of any observer or any special observational circumstances. The most important group of objections exploits the high degree of variability of colors. Because there is no perceiver-independent, well-motivated standard for choosing among perceptual variants with respect to color properties, variability of colors is supposed to refute color objectivism.

Most objectivist and dispositionalist theories of color have tried to resolve the challenge raised by color variations by drawing a distinction between real and apparent colors. This paper considers such a strategy to be fundamentally erroneous. The high degree of variability of colors constitutes a crucial feature of colors and color perception; it cannot be avoided without leaving aside the real nature of color. The objectivist theory of color defended here holds that objects have locally many different objective colors. Most color variations are then real and result from the extreme richness of color properties.

1. Introduction

Our visual world is filled with colored objects and substances: lemons are yellow, some birds are blue, blood is red, and snow is white. But under many different circumstances our perception of colors can change: A lemon can appear red in monochromatic light, a drop of blood becomes partly yellowish when observed through a microscope, and snow can be pink behind sunglasses. In addition, we know that chromatic perception is directly related to the visual apparatus of the observer: Some color differences visible for most human observers are not detectable by, for example, colorblind people. In light of all these examples, is it still plausible to argue that lemons are yellow, blood red, and snow white, or should we modify our statement and say, for example, that lemons are yellow in a certain light at a certain distance and for a certain group of observers only?

This paper defends an objectivist theory of color. It shall affirm that despite all the variations that influence the chromatic appearances of objects and substances, colors exist independently of any observer or any special observational circumstances. Unlike most color objectivist theories, this one claims that uniform colored surfaces have many different objective colors. I contend that rejecting the idea that an object can only have one color locally solves most of the difficulties faced by objectivist theories.

Arguments against color objectivism are numerous, but the most extensive group of objections relies on the very wide variability of colors. These objections can be divided into two main categories. When variations of external circumstances are invoked, these objections usually seek to show that colors cannot be intrinsic, non-relational properties of objects. Berkeley's microscope argument[1], for example, has been used to demonstrate that colors depend essentially upon the circumstances in which they are seen; therefore they cannot be genuine objective properties.

In addition to color variations due to external circumstances, we know that perceived colors vary according to differences in the perceptual apparatus of the observer. These

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[1] G. Berkeley 1713/1998, The First Dialogue, 71-73.

variations can be divided in three main categories: intrapersonal, interpersonal and inter-species differences.

One famous case of intrapersonal color variation, namely chromatic adaptation, has been used to prove that there is no independent and non-arbitrary way of choosing among the different adaptative states of the viewer, and as a result, there is no way to know what the real objective colors of objects are.[2]

Another way to stress the strong link between color appearances and the nature of their observers is to appeal to differences among human observers, in particular to color vision deficiencies such as color blindness. We know that a small proportion of the human population makes discriminations different from those of the majority of trichromatic observers, and that there is strong evidence suggesting that objects appear different with respect to color to these people than to the rest of the human population. These interpersonal differences in color vision can be taken to show that colors are always relative to the observer and that any observer-independent color characterization is therefore false.

Finally, recent studies in comparative color vision have emphasized that variations in inter-species color vision show that there is no one single type of property detected through color vision by all living organisms, but a manifold. Having acknowledged this great variety of color visions, all attempts to identify colors with one single type of property detected by the human visual apparatus become apparently very arbitrary and therefore suspicious.

I shall defend the view that the challenge of color variation, both external and internal, is inescapable for any theory of color. High variability of color constitutes an important characteristic of colors and color perception, and therefore it cannot be avoided without leaving aside the real nature of color. Most objectivist and dispositionalist theories of color have tried to overcome the challenge raised by color variations by drawing a distinction between real and apparent colors. I consider such a strategy to be fundamentally erroneous. The objectivist theory of color I defend holds that objects have many different objective colors locally. Most color variations are then, in fact, real and result from the extreme richness of color properties exhibited by surfaces.

I therefore claim that most objectivist theories of color and many objections to these rest on the same mistaken premise that objects can have at most only one color. I shall call this premise the “Color Unicity Principle” and its use (implicitly or explicitly) to refute objectivism the “Color Unicity Error”.

To shed some light on this new approach to color objectivism, I will start by investigating the philosophical consequences of dropping the Color Unicity Principle: Notorious cases of color variation will be explained within this new framework and the objectivist theory advocated will be compared with similar philosophical views. I will then attempt to draw the outline of a physicalist theory of color by identifying colors with reflectances over one or many wavelength interval(s). Finally, I will show how the new objectivist color theory advocated here can be applied to iridescent colors.

2. External color variations

Distance, motion, composition and intensity of incident light can strongly affect the colors of objects. As most subjectivists recognize, there is no non-arbitrary way to choose between circumstances that reveal the real colors of objects. If objectivism about color is coupled with the Color Unicity Principle, the difficulties raised by the variations of circumstances seem unavoidable. If objects are supposed to have at most one color locally, color changes associated with variation of viewing conditions must involve some kind of illusion. The

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[2] *Cf.* Campbell, K. 1979.

argument against objectivism based on external color variation relies on the following two assumptions:

1. An objective property is not dependent on any observer or viewing conditions.
2. An object can have locally at most one color.

If objective color is independent of viewing conditions, a change of color induced by a change in viewing conditions cannot be equated with an objective color change. In addition, if an object can have at most one color and the color change induced by a change in viewing conditions is not an objective color change, one can conclude that at least one color perceived through a change of viewing conditions is not real.

Most objectivist and dispositionalist approaches to external color variations distinguish those viewing conditions which make possible veridical perception of colors and those which lead to erroneous or illusory color perception. But, as often stressed by C.L. Hardin, there is no non-arbitrary way to distinguish between "kosher" and "not kosher" viewing conditions.

> I shall argue that contexts are interest-relative and irreducible to a single context, so there is no unique set of standard conditions under which objects are to be seen in their "true" colors (Hardin 1983, 806)

Consider, for example, the case of the illuminant. The optimal lighting condition for color perception is usually identified with the use of some white light. Selecting some white light as the standard illuminant allows one to circumvent the problems associated with variations of external conditions. Consider the following case. A lemon in daylight appears yellow, but in a monochromatic light it can appear red, green, or blue. According to the Unicity Principle, an object cannot be of several colors, so one has to admit that some of the colors exhibited by the lemon are not real. The problem is then to choose among all these different colors and give some kind of justification for this choice.

This strategy is fundamentally mistaken, not only because there is no way to choose between the colors exhibited by an object in different lighting conditions, but also because it doesn't fit into the phenomenology of color perception. I think that the greatest strength of color objectivism is that it does justice to the phenomenology of color experiences in locating colors exactly where they appear to be, that is, on the surfaces of objects. If, on the other hand, to avoid problems connected with external variations, the objectivist qualifies as apparent or illusory the colors observed in special lighting conditions, the objectivist deviates from his original objective and misrepresents the phenomenology of colors. Theories relying on the Unicity Principle, as I will show, cannot explain why the same surface in different lighting conditions can appear to have different colors and at the same time appear to be unchanged.[3] For example, when we look at a banana in daylight and then again with a "red" light, we notice a chromatic difference, even though we see that the banana has remained unchanged.

I believe that the phenomenon of color constancy manifested by color perception in varying lighting conditions has been wrongly assimilated with the Unicity Principle. Color constancy refers to the invariance of perceived colors under changes in the composition of the illuminant. If we look at a banana under a blue sky and then again later at sunset, the color of the banana seems unchanged even though the light is very different at these two times of day. Color constancy is assumed to be fundamental because it guarantees a stable visual world, allowing subjects to keep track of objects despite external changes. The fact that colors don't change with change of light has been wrongly assimilated to the idea that objects have at most one color.

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[3] *Cf.* §6.

As noted by Brainard and Wandell (1992) and Wandell (1995), color constancy, defined as the invariance of perceived surface colors under changes of the illuminant, is limited in "normal conditions" and very poor in lighting with abnormal spectral content (e.g. a sodium arc, or early fluorescents). B. J. Craven and D. H. Foster (1992) show that subjects are very good at correctly attributing changes in the color appearance of a scene either to changes in reflecting properties of the surfaces, or to changes in the spectral composition of the illuminant.[4] These experiments suggest that color constancy should not be confused with constant chromatic perception. Color constancy is essentially dynamic: it is an ability to extract stable properties from changes in perceived colors. Such is the case in the example given above of looking at a banana in daylight and then again with a monochromatic light. As stressed by B.J. Craven and D.H. Foster, such color changes are correctly attributed to changes of the incident light rather than to changes of the object's physical properties. I therefore propose that color variations emerging from changes in illumination result from perceiving different colors of the same object O. Rejecting the Unicity Principle allows us to explain why changes in illumination can be perceived as color changes without having to admit that the object's properties have changed. If a surface S has many colors, changes of the colors perceived due to a change of the illuminant can be explained by differences regarding the colors of S detected by the visual system. As this paper will later clarify,[5] changes in lighting conditions can elicit different perceptual capacities. Therefore, admitting that an object can appear to have different colors in different lighting conditions does not imply that the color perceived with a "special" illuminant is illusory, nor that the object has changed.

3. Internal Color Variations

Perceived color can vary with external circumstances, like lighting conditions, but some color variations are only related to differences in the perceptual apparatus of the observer. I will call these variations "internal color variations" and divide them into three main categories: intrapersonal, interpersonal and inter-species variations. Like external color variations, internal color variations have been presented as constituting a serious threat for color objectivism. Why is this, exactly?

The alleged danger for color objectivism due to internal variations is quite similar to the one related to external color variations. In short, if an object can be perceived to have different colors by the same observer in different visual states or by observers having different visual apparatuses, the Color Unicity Principle cannot be preserved unless there is a way to single out the object's true color among the huge diversity of perceived colors. The strategy chosen by most objectivists and dispositionalists to achieve this goal is to restrict veridical color perception to a particular group of observers in a specific visual state. However, this strategy, as often stressed, runs up against the problem of arbitrariness: there seems to be no way to legitimate the choice of one particular group of observers.

I maintain, on the contrary, that there is no reason to restrict veridical color vision to a particular group of observers. However, acceptance of a large variety of color appearances due to differences in color vision doesn't refute color objectivism. In fact, internal color variations would refute color objectivism only if the Color Unicity Principle were true. To clarify how color objectivism can be combined with internal variation of color appearances, let us consider some well-known examples.

The most widespread cases of internal and intrapersonal color variation are cases of chromatic adaptation. If, for example, the observer's eyes are exposed for a long time to a

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[4] *Cf.* B. J. Craven and David H. Foster 1992.

[5] *Cf.* §5.

long-wavelength light, his subsequent color perception will be momentarily modified and the color of objects will appear to be more greenish. The physiological reason for this chromatic variation is that temporary changes in the sensitivity of neurons follow their intense stimulation. The apparent problem for color objectivism is the following: If colors are objective properties, how can some physiological changes in the observer's visual system affect the colors perceived? In other words, if colors are objective properties of surfaces, how can changes in color experience be accounted for physiologically and not by some changes on the level of objects' surfaces?

I suggest that the reduction of the sensitivity of the visual system following prolonged stimulation gives rise to a different but no less veridical chromatic perception. If an object has more than one color locally, changes in the observer's visual system can lie at the source of changes of the chromatic properties detected by the modified chromatic system. In the case of chromatic adaptation presented above, the continued exposure to long-wavelength light reduces the sensitivity of long-wavelength receptors. In contrast to the "normal" color experiences of a trichromatic observer, chromatic adaptation limits the access to some surface properties, namely their reflectance in the long-wavelength band. This reduced "sensitivity" is often held to lead to an illusory or erroneous color experience. I claim, on the contrary, that this change in color perception gives access to different but real color properties.

There are, in fact, many situations where similar reductions of sensitivity are exploited to reveal hidden physical properties. For example, some evidence at a crime scene, such as fingerprints and body fluids, are often invisible to the naked eye, but can be revealed and made plainly visible with the use of a particular light source and special glasses. The glasses used in such a situation are filters, able to block a special band of wavelengths. As in the phenomenon of chromatic adaptation, wearing this kind of glasses limits the color perception of a forensic investigator to a smaller part of the visible spectrum. Chromatic discontinuities corresponding to fingerprints or particular smears perceived with forensic methods are not considered as being erroneous or illusory. They are, on the contrary, admitted as evidence in court. Hence, there seems to be no reason to claim that colors perceived in cases of chromatic adaptation should be less real and reliable.

As is very often stressed, there is a great amount of variability among human observers regarding their color perception. Most of these variations can be explained by physiological differences. Colorblindness, for example, can be explained by the lack of one or more of the three types of photoreceptors (cones). Parallel to chromatic adaptation, this reduced number of cone types decreases the eye's sensitivity in some region of the light spectrum. Therefore, as in the case of chromatic adaptation, there is no reason to suppose that the colors perceived by a colorblind subject are less real than the colors perceived by a "standard" observer. To qualify as deficient or illusory the chromatic perception of colorblind subjects is certainly not an option for the objectivist. As stressed above, one of the main advantages of color objectivism is its holding that colors are directly presented in perception as they really are. If colorblindness were equated with some perception deficiency or illusion, there would be no way for the objectivist to claim that trichromatic color is veridical and reliable. Trichromatic human color vision stands in exactly the same relation to some birds' color vision as color blindness stands to trichromatic vision. Studies on comparative color vision suggest, in effect, that some birds, fish and turtles have at least four spectrally distinct types of photoreceptors (cones) and that pigeons may be pentachromats. If differences in colorblindness resulting from the lack of one cone type were considered to yield some deficient or illusory color vision, "normal" human color vision should also be considered as deficient or illusory in comparison to tetra- and pentachromatic vision.

Interpersonal and inter-species color variations are perfectly compatible with color objectivism insofar as such variations are explained by true objective color differences rather than in terms of color vision deficiency. That two subjects, whether or not they belong to the same species, can see the same object as having different colors in the same conditions would not be problematic if the Color Unicity Principle were not presupposed. If objects can have many different colors locally, differences in color vision can be accounted for in terms of differences in the objective colors detected by the various visual apparatuses. Given that birds and human beings have different visual systems, it seems very reasonable to suppose that they detect different objective properties. However, there seems to be no reason to deny that the objective properties detected by these different visual systems are real colors.

4. Other recent realist approaches

Recent versions of color objectivism resemble in some respect the view advocated here. Byrne and Hilbert, for example, concede the following:

> Since a single surface falls under many different reflectance-types (in fact, infinitely many), there need not be any conflict between color appearances across species. Goldfish and human beings see objects as having different colors, but reflectance physicalism gives no reason to suppose that if one species is right the other must be wrong (Byrne, A. & Hilbert, D. 2003, 16)

So according to Byrne & Hilbert, variations in color vision across species can be explained by variations relative to the physical properties, namely reflectance-types, detected by their different perceptual systems. However, they don't explain variation in normal vision in the same way. The problem they consider originates from Hardin (1993):

> [Imagine that all of the] hue chips manufactured by the Munsell Company covering [the] 5 Blue-Green to 2.5 Green range were randomly spread out before you to be separately viewed on a dark gray background in North Daylight. One of them would be your considered choice for unique green. Your colleague might make a different choice. If so, which of the chips is unique green? (Hardin 1993, 80)

Contrary to what they say about inter-species color variation, Byrne & Hilbert seem to agree with Hardin that color realism needs an independent standard that would determine which chip, if any, is unique green. The problem, they acknowledge, is that there is no such knowable standard:

> Thus we are prepared to countenance "unknowable color facts"-that a certain chip is unique green, for instance. (Byrne, A. & Hilbert, D. 2003, 21, n. 50.)

But why not simply claim that the same chip can be both unique green and bluish green? Why not admit, like when it comes to color variation between color species, that there need not be any conflict of color appearances between two human subjects? Unlike Byrne & Hilbert, I don't see any reason why these two kinds of color variations should be treated differently and I suspect Byrne & Hilbert's stance regarding normal color variations to be motivated by some implicit appeal to the Color Unicity Principle.[6]

Another strategy for solving Hardin's problem of color variations among "normal" human observers is to relativize colors to perceivers.[7] Like the approach defended here, such relativisation amounts to rejecting the Color Unicity Principle. Consider, for example, Cohen's answer to Hardin's problem.

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[6] Note that if the same chip is both unique green and bluish green, we must admit that the term "unique green" refers to different objective colors. When viewing a range of Munsell chips, perceivers can disagree about which chip is unique green. Unless there is some objective property shared by the chips judged by the observers to be unique green, we should admit that "unique green" refers to different objective properties.

[7] For simplicity, I intentionally omit relativization to circumstances.

> Luckily, there are non-eliminativist ways of accepting the absence of a perceiver-independent standard for C1's color. Namely, we can hold that the alternative representations of C1's color (the way it looks to you, the way it looks to your colleague) are both veridical. There are a number of ways of fleshing out this suggestion, but one of the most popular is to construe colors as relativized to perceivers. (Cohen, J. 2003, 26)

Like the view defended here, Cohen allows that two chromatically different perceptions of the same object can both be veridical. One and the same object can therefore have many different colors simultaneously. However, Cohen's relativism is far too liberal, contradicting our intuitions regarding color objectivity. Cohen's relativism implies in effect that the surface of an object has not a color C simpliciter, but rather a color C for a subject S in conditions C'. The problem is not that relationalism attributes infinitely many colors to every object. It is rather that it prevents any two perceivers from seeing the same chromatic property. Even if two subjects, A and B, were to have identical visual systems and were to observe the same object in identical circumstances, the relativist would be committed to saying that the colors perceived by A and B are different[8]. If A and B see the same lemon in the same circumstances, the lemon would be either yellow for A in C or yellow for B in C. In addition, as noticed by Byrne & Hilbert (2003, 58), a simple explanation of our behavior based on color discrimination would not be available to the color relativist. Object reidentification based on color recognition, for example, could be threatened by even minor changes in viewing circumstances.

Another major problem for color relativism is that it departs from our color phenomenology and paradigmatic color ascriptions. When looking at a lemon, I don't see any chromatic relation between the lemon and myself. The lemon appears to be yellow and this property seems to belong to the lemon, like its shape and its size. The monadic or intrinsic character of colors is also mirrored in our ordinary color ascriptions. We don't say that "the lemon is yellow for me in the present circumstances"; we simply say "the lemon is yellow." Certainly, color ontology cannot be derived from phenomenology and ordinary language. However, if an ontological theory is anchored in our everyday language and perceptual experiences, then this is, ceteris paribus, an advantage.

In fact, once we recognize that objects have many objective colors, there is no need to relativize colors. Changes with respect to observational circumstances, for example, can allow the perceiver to perceive different colors than the colors perceived in more usual circumstances. There is no reason to say that the colors perceived in circumstances C1 are more or less real than the colors perceived in circumstances C2. And there is no reason to hold that the colors perceived in circumstances C1 should be relativized to C1 and colors perceives in circumstances C2 should be relativized to C2. This point is crucial because different variation parameters of color vision could elicit the same discriminatory capacity and hence the same color experiences. To see this point, consider the two following cases: a normal trichromat perceiver with naked eyes observes a white surface illuminated by a red light, and a normal trichromat perceiver with red tinted glasses observes a white surface illuminated by a white light. Although the circumstances in each case differ greatly, we can plausibly assume that the reddish color of the white surface experienced by the subject in both cases is identical with a unique property. In effect, the red tinted glasses used in the second scenario are filters able to block the medium- and short-wavelengths. Wearing such glasses therefore confines chromatic discriminations in the long-wavelength band. The use of a light composed exclusively of long wavelengths would have sensibly the same effect. The absence of short-

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[8] The relationalist could choose to relativize color to types of visual systems rather than to particular observers. In this case, the problem would be to justify the acceptable types of visual systems vs. the unacceptable types of visual systems.

and medium-wavelengths in the light would prevent color vision from operating in the short- and medium-wavelength band and therefore restrict chromatic perception to the long-wavelength band.

Although very liberal regarding color attribution, the approach defended here is not too permissive and, in contrast with color relativism, it supports simple behavioral explanations based on color recognition and explains many similarities of color experiences in terms of identities of colors perceived.

5. A physicalist approach to color pluralism

Having exposed the philosophical advantages of color pluralism, I propose to consider how color pluralism can be implemented in a physicalist theory of colors. The approach defended so far is objectivist in the sense that it maintains that colors are mind-independent properties. Contrary to color subjectivism, this theory claims that colors can exist without subjects to perceive them. Although color objectivists are mostly color physicalists, color physicalism should still be distinguished from color objectivism. Color physicalism refers to theories that identify colors with particular physical properties. Because the objective color pluralism defended here seems to face great resistance, I propose to give a more tangible idea of how colors should be understood in this framework by giving some clues as to what these colors could be from a physicalist perspective.

The color physicalism I want to propose is a version of reflectance physicalism. Reflectance physicalism[9] identifies colors with surface spectral reflectance: the proportion of incident light a surface is disposed to reflect at each wavelength. Reflectance physicalism is open to many objections. To take only one example, we know that objects with different reflectances can match in color under a given illuminant. It therefore seems inappropriate to identify the colors of physical objects with spectral reflectances, since objects, which commonsense grounds establish to have the same color, can have different spectral reflectances. This problem, known as the metamerism problem, has prompted many philosophers to give a modified version of reflectance physicalism. Byrne and Hilbert (1997, 2003) propose to identify colors with types or sets of reflectance. The version of reflectance physicalism I want to defend is close to Byrne's and Hilbert's proposal, but leads to quite different consequences. Like Byrne and Hilbert, I think that the problem of metamers forces the color physicalist to admit that colors perceived by human observers cannot be identified with specific surface spectral reflectances (SSRs), *i.e.* the proportion of incident light the object is disposed to reflect *at each wavelength*. Unlike Byrne and Hilbert, I don't think colors should be identified with types or sets of reflectances, but rather with *reflectances over one or many different range(s) of wavelengths.*

As recognized by most reflectivists, the colors perceived by human observers are strongly tied to the human visual system. Because there are only three kinds of human color receptors, whose sensitivity ranges approximately from 400 to 525 nm for short-wave cones, from 435 to 640 nm for middle-wave cones, and from 450 to 680 nm for long-wave cones, human color vision is too coarse to discriminate among all SSRs. Based on Edwin Land's experiments[10] on color constancy, Hilbert (1987) suggests that perceived colors should rather be correlated with triples of integrated (surface) reflectance (TIRs), that is, integrals of reflectance above the sensitivity ranges of short, medium and long wave sensitive retinal cones. Integrated reflectance measures the percentage of incoming light a surface is disposed to reflect in a specific wavelength interval. *Triples* of integrated reflectance correspond to the

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[9] Hilbert, 1987; Byrne and Hilbert, 1997, 2002; see also Matthen, 1988 p24; Tye, 1995, pp. 144-150.

[10] See Land, E. H. 1977.

percentage of incoming light a surface is disposed to reflect in *three* wavelength intervals. By choosing wavelength intervals matching the sensitivity range of human color receptors, we get, according to Hilbert, the reflectance properties singled out by "normal" human color vision. As acknowledged by Hilbert, those reflectance properties are strongly tied to the human makeup. If the cone sensitivities had been different for instance, the standard human observer would have seen different colors. However, the fact that TIRs are relative to human color vision does not condemn their objectivity. It only shows that human color vision detects properties which are not of general interest. TIRs are therefore objective and anthropocentric colors.[11]

Although the colors perceived by "normal" human observers in "normal" conditions can be identified with TIRs, there is no reason to identify colors with TIRs *only*. In fact, TIRs are one subset of colors, namely those colors perceived by "normal" human observers in "normal" conditions[12]. Having acknowledged that integrals of reflectance above the sensitivity ranges of short, medium and long wave sensitive retinal cones constitute a subset of colors, my proposal is to identify colors with any single- or multi-set of integrals over different ranges of electromagnetic wavelengths. To put it very roughly, reflectance, defined as the proportion of incident light a surface is disposed to reflect, can be specified for any kind of light composed of one, many or an infinity of wavelengths. The spectral reflectance function of a surface, for example, corresponds to the surface's power to reflect a fraction of incoming light on a *per wavelength basis*. My physicalist proposal, then, is to identify colors with the dispositions of a surface S to reflect a determinate proportion of any incident light L. Unlike SSRs, these reflectances are not exclusively relative to "white" lights composed of a continuous spectrum of wavelengths. Color perception, as shown in many psychophysical experiments, can also be relative to lights composed of very few wavelengths.

My basic physicalist proposal can then be summed up as follows:

- (i) Colors are reflectances over one or many ranges of wavelengths.
- (ii) Each surface has as many colors as there are ways of combining wavelength intervals, *viz.* an infinity.
- (iii) According to (i), SSRs and TIRs are two color subsets. SSRs correspond to reflectances relative to all the wavelength intervals containing a single wavelength. TIRs correspond to reflectances relative to three wavelength intervals ranging approximately from 400 to 525 nm, from 435 to 640 nm, and from 450 to 680 nm.

How does this outlined physicalist proposal fit with the objective theory presented above? In particular, how does it deal with the problem of color variations?

We affirmed that external color variations due to change in lighting conditions, for example, are unproblematic for objectivism as long as it is admitted that a uniform surface can

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[11] Zoltan Jakab has argued that TIRs could not be identified with perceived colors. According to him, and contrarily to what is assumed by most reflectivists, the physicalist characterization of perceived colors relies essentially on the receptor sensitivities. Characterization of perceived colors in terms of reflectance has therefore to be corrected by the receptor sensitivities, expressed by spectral sensitivity functions. The problem is that, according to Jakab, once integration of reflectance are corrected with receptor sensitivities, the resulting color characterization depends on some observer's parameters and cannot be said to be objective any more. If Jakab's argument against Hilbert's theory is valid, the present account is also vulnerable to the same objection. One possible answer to Jakab's argument is to notice that cone sensitivities do not change which properties are perceived, but only how well they are perceived. In any case, the present account is only a proposal showing how color pluralism could be accommodated with a physicalist account of color. Such a proposal would of course need empirical confirmation

[12] The word "normal" is not intended here to refer to a privileged class of observers, but only to specify a statistical average observer.

have many different objective colors. The physicalist approach suggested here sheds some light on how these variations can be explained.

As dispositional properties, all reflectances over wavelength intervals are actual properties of objects. However, their manifestation depends on particular conditions. The use of a monochromatic light, for example, prevents most colors from being manifested. Although colors perceived by "normal" observers correspond in most natural circumstances to reflectances over three wavelength intervals ranging approximately from 400 to 525 nm, from 435 to 640 nm, and from 450 to 680 nm, special conditions, like the use of a monochromatic light, can focus color vision of "normal" observers on different colors.

A ripe banana seen in daylight by a "normal" observer appears yellow because its color corresponds to a determinate reflectance over three wavelength intervals. When that same banana is viewed in some monochromatic light, however, it can appear red, because the perceived color corresponds in that case to a determinate reflectance relative to a light composed by a single wavelength.

Internal color variations are also easily explained by the physicalist approach suggested. For example, most common color vision differences are related to differences in photoreceptor sensitivity. Dichromats, for example, have only two populations of cone cells (as opposed to three for trichromats). Therefore, unlike trichromats, the colors they perceive are identical with reflectances over only two wavelength intervals. Anomalous trichromacy, on the other hand, is characterized by a shift in the sensitivity of one or more cone types. According to my proposal, anomalous trichromacy can then be characterized by the fact that the reflectances detected by an anomalous trichromat are relative to different wavelength intervals. Although reflectances perceived by an anomalous trichromat are relative to three wavelength intervals like reflectances perceived by "normal" subjects, one or more of these intervals is not identical with those wavelength intervals characterizing "normal" color vision.

From the assumption that surfaces have infinitely many colors, should we conclude that each surface has all possible colors? If this is the case, how can we discriminate surfaces from their colors?

Although surfaces possess infinitely many colors, i.e. reflectances over one or many wavelength intervals, each surface has a characteristic set of colors. Two surfaces are the same color if they have the same reflectance over the same wavelength interval(s). According to this definition, the color "red" of a banana in a monochromatic light is essentially different from the color "red" of a tomato in daylight, because they correspond to reflectances over different wavelength intervals. When viewed in monochromatic light a ripe banana appears "red" because its perceived color is identical with the reflectance over a *unique* wavelength interval composed of only one long wavelength. When a standard observer looks at a tomato in daylight, the color "red" exhibited by the tomato is identical with a reflectance over *three* wavelength intervals ranging approximately from 400 to 525 nm, from 435 to 640 nm, and from 450 to 680 nm. The assertion that surfaces have infinitely many colors should not therefore be assimilated with the assertion that surfaces share the same colors. Moreover, to say that a banana illuminated by a monochromatic light composed of long wavelengths looks "red", should not obliterate the fact that its chromatic appearance is different from the color exhibited by a tomato in daylight. As often stressed by Katz, to each specific illumination correspond specific colors:

> *Within a visual field illuminated normally as regards quality we cannot set up colour-impressions which are equal in every respect to those which we see in chromatically illuminated fields*. (…) In the illumination provided by gas or electricity, we do not see a plain blue (*i.e.*, a blue in illumination of normal quality), but a blue in *reddish-yellow* illumination. (Katz 1935, p. 192)

The use of a monochromatic light significantly reduces our discriminatory capacities, because differences of reflectance relative to a single wavelength are much less numerous than differences of reflectance relative to many wavelengths. This simple fact is enough to explain why “white” lights are preferred for color perception and object recognition. If, however, two surfaces reflect the exact same proportion of a monochromatic light, there is no reason to deny that they have the exact same color. In the pluralistic framework proposed, two surfaces can share the same color and yet be chromatically distinguishable.

6. Color pluralism and color incompatibilities

I have argued that color objectivism can face classical objections based on color variations insofar as a surface has locally many objective colors. A first *prima facie* worry is that such color pluralism is too liberal. A profusion of color properties would negate all color distinctions by attributing to objects infinitely many colors. In effect, if differences regarding color vision are accounted for in terms of differences in objective colors perceived, it seems possible for one object to be simultaneously red, green and blue, provided there are observers who perceive this object as red, green or blue.

My answer to this worry is twofold. I will start by arguing that color terms such as “red”, “green” and “blue” correspond to color categories which can be applied to different color properties. Therefore the fact that two observers describe their experience as “red” does not imply they perceive the same color. The second part of my answer will consider the limits of intersubjective color variation. I will argue in particular that it is impossible for one object to have all possible colors. The assertion that surfaces have many different colors, even infinitely many colors, does not therefore imply that surfaces share the same colors.

Consider again the objection against color pluralism. If S and S’ are two subjects with different color vision looking at the object x in the same circumstances C, it is plausible that:

(1) x looks green for S in C
(2) x looks blue for S’ in C

Provided S and S’ are not hallucinating, the pluralist approach defended here sustains that:

(3) x is green and blue.

On the other hand, color discrimination and object recognition suppose that (3) is false: green and blue are incompatible properties. Therefore

(4) ~ (x is green and blue)

To avoid the contradiction of (3) and (4), one could choose, like most objectivists, to reject (1) or (2) by arguing that at least one of the two experiences is hallucinatory. My strategy here is rather to hold that the referents of “green” and “blue” in (3) and (4) are different, such that there is no contradiction involved.

We are able to discriminate among several million colors, but the color categories we use to describe our chromatic experiences are, by comparison, very limited. We don’t have a particular color name or category to label every different color sample or color relation we can perceive. For instance, words like “blue”, “brown” or “pinkish” refer respectively to a large number of distinguishable color samples and viewing circumstances. When looking at a ripe banana in a red light, for example, one can accurately say that this banana looks red. The appearance of a ripe banana in a red light is different from the way a ripe tomato looks in daylight, however, it seems perfectly correct to describe both appearances as being “red”. Although the use of color terms is very liberal: they are used to perform very different tasks in very different situations, there is one particular use of color terms often favored in our culture.

As stressed by Mausfeld[13], the development of coloration and dyeing techniques has influenced our way of dealing with colors. With standardization of color for industry purposes and the birth of colorimetry, color experiments have been focused on the perceptual matching of decontextualised small colour patches. This practice has also influenced the ordinary use of color terms. In effect, color terms are often used to compare the surfaces of objects in a white light while leaving aside differences of texture, glossiness, fluorescence, etc. We typically say that a banana is yellow, even though we may realize that a banana can look "red" or "green" in a variety of circumstances. I suggest that the color incompatibility expressed in (4) corresponds to this restrictive, but important, use of color terms. Color terms can pick out many different properties perceived by different observers in very different circumstances. However, for pragmatic purposes, one very small subset of these properties is privileged for comparison of surfaces. The fact that we typically talk about *the* color of a surface does not therefore contradict color pluralism, insofar as we note that color discourse is ordinarily applied to a small subset of colors. Given the extraordinary variability of color experiences, it is not surprising that color categories and color naming are anchored in a relatively stable and widespread color subset limited by paradigmatic viewing angle, light source and atmospheric composition. The proposition (4), expressing the incompatibility of "green" and "blue", relies on the pragmatic limitations of the color subset used in color matching and color comparison discourse. This point can be illustrated by the "banana case" above. Unless we specify some unusual lighting or specific conditions of the observer's visual system, the direct answer to the question "What color is a ripe banana?" is "yellow". It is only when we are directly confronted to "unusual" circumstances or observers that our assumption about the uniqueness of colors becomes problematic. Although we may choose to describe as yellow the color of the banana in a red light, the category "yellow" will not fully capture the color perceived by the observer. Such situations require therefore the application of our color categories to be extended beyond paradigmatic contexts of color attribution. To describe a banana perceived in a red light as red implies therefore to attribute the concept "red" to properties excluded by ordinary conversational constraints.

The same goes for intersubjective color differences. Since color classification relies on the perception of color similarities, ordinary color attribution implies some uniformity of color experiences among observers. We know however that there is a high variability of color vision among human observers which could preclude good communication among observers. So, to accommodate with differences among individuals, it has been suggested that color naming and categorization rely on the color perception of the majority (non-anomalous trichromats).[14] When we say that a ripe banana is yellow, we implicitly take into account the color subset perceived by the majority. However, from time to time, color vision differences can result in disagreement regarding color attributions. It is only when observers disagree about color attributions that we realize that color properties exceed the properties perceived by the majority. Propositions like (4) express the fact that ordinary color discourse is limited to colors observed by non-anomalous trichromats in standard conditions. The fact that ordinary talk about colors is constrained by conversational presuppositions has however no ontological implications. In particular, the fact that color attributions rely on the color vision of the

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[13] Mausfeld, R., 2003, "'Colour' as Part of the Format of Different Perceptual Primitives: the Dual Coding of Colour", in *Colour Perception: From Light to Object*, R. Mausfeld and D. Heyer (eds.), Oxford: Oxford University Press.

[14] Cf. Kimberly A. Jameson,

majority does not imply that colors perceived by an observer belonging to a minority group, like a tetrachromat or a dichromat, are illusory.

The apparent contradiction between (3) and (4) can be explained in the following way. The proposition (3) expresses the fact that when viewing the same object in the same circumstances, people can perceive different colors. There is however no color name for each color property. In particular, there is no color category for the colors perceived by the observers of the minority. To express their disagreement with the majority, the observer belonging to the minority can choose to drop the conversational constraints and apply ordinary color terms to the colors they perceive. We can therefore conclude that, like in (4), ordinary use of color terms refers to the color subset perceived by the majority, but that the meaning of color terms can sometimes be widened to refer to colors perceived by non-standard observers like in proposition (3).

The objection against color pluralism pointing out to the contradiction of (3) and (4) can be responded by underlining variation in the attribution of color terms. I want now to address the ontological question of color incompatibilities expressed in (4). Although there may be a variety of reasons to hold that a surface can have at most one color, I think that the plausibility of the Unicity Principle is mainly derived from color incompatibilities. It is often assumed that color incompatibilities expressed by propositions like:

(i) It is not possible for something to be *both* red and green all over at the same time.

can be generalized and justify the general proposition:

(ii) A surface cannot be colored with more than one color at the same time (color unicity principle).

I think that it is possible to accept propositions like (i) and nonetheless deny the truth of (ii). (i) is true, because the meaning of color terms, such as “red” and “green”, is limited to the colors perceived by a particular type of observers in particular conditions. As argued earlier, restricting color attribution to a particular color subset maximizes success in communication. Color incompatibilities, like (i), correspond to incompatibilities among particular colors. It is not possible for something to be both red and green all over, when “red” and “green” refer to colors perceived by a non-anomalous trichromat in standard conditions.[15] It is possible however for something to be red and green all over at the same time if the referents of “red” and “green” extend to all colors.

Contrarily to what seems assumed, color incompatibilities do not lead to the Color Unicity Principle, because relevant color incompatibilities are restricted to a particular color subset. Only a limited group of colors are in fact relevant for ordinary color attributions. When describing the color of a ripe banana, we do not consider special viewing conditions like illumination by a monochromatic light. Although limited to a particular subset, ordinary color incompatibilities play a major role in object recognition. It is only because viewing conditions are pretty stable that an object can be tractable through its color or that an object’s color change can be a reliable indicator of its physical change. Ordinary color attributions single out particular observers and viewing conditions. The contrast between standard vs. non-standard observers and viewing conditions is not, however, ontologically significant. As stressed by

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[15] According to the physicalist suggestion given in §5, color incompatibilities amount to the fact that for a given light L there is a *distinctive* ratio of L reflected by a particular surface. In other words, a particular surface cannot have many incompatible colors, because it cannot reflect differently the same light. On the other hand, colored surfaces have infinitively many colors, because they can reflect an infinity of different lights.

Hilbert, color language and color perception 'give us anthropocentrically defined kinds of colors and not colors themselves'.[16]

Color incompatibilities play a major epistemic role. However, once it is admitted that these color incompatibilities are restricted to anthropocentric colors, the main motivation supporting the color unicity principle vanishes. Objective color pluralism can therefore maintain that a banana has infinitely many colors and nonetheless give an account of common sense claims about color, such as "A banana is yellow, it is therefore neither blue nor red".

7. Color variations and color constancy

We have considered so far those changes in color experiences that are not perceived as *intrinsic color changes*. Unlike, for example, color changes characteristic of fruit maturation or color changes in chameleons, chromatic changes relative to changes in the observational circumstances or in the subject's visual system are not perceived as *changes in the colored objects themselves*.

The distinction between intrinsic and extrinsic color changes is, in my view, crucial, because it wipes out typical objections to color objectivism. Consider the following problem due to Hardin:

> We see two specimens in daylight; they match. The first we had already decided was K, since it looks K in daylight, so we feel obliged to call the other K as well. But in incandescent light the first looks K-ish still, but the second does not look K-ish. Shall we continue to call it K? (Hardin, C.L.1988, 75)

We have acknowledged so far that the case presented here by Hardin doesn't threaten our objectivist theory of color, because we can admit that the colors perceived in daylight and in incandescent light can be different but nonetheless objective. But the quotation from Hardin points to yet another issue: the color constancy problem. Even though change in color circumstances is perceived as a genuine chromatic change, there is a sense in which the color perceived through a change of circumstances doesn't change. How is it possible to reconcile the two following claims?

i. Variation of viewing circumstances brings about changes in the perceived colors.
ii. Variations of viewing circumstances don't bring about changes in the perceived colors

I suggest that external color variations, expressed in (i), and color constancy, expressed in (ii), are compatible provided we acknowledge that there are two different meaning of the word "color".

I have argued so far that a uniform surface has many different colors. This, of course, doesn't imply that a uniform surface has any color. It is essential to notice that the set of colors characterizing a uniform surface is strictly correlated with the object's physical constitution and that only a change in the object's physical or chemical properties can change the set of colors characterizing the object's surface. We know, for example, that given a particular color vision system, there is a systematic correlation between color variation and variation in circumstances: A white object in daylight will appear blue when illuminated by short wavelengths and red when illuminated by long wavelengths. This systematic correlation can nonetheless be undermined if the object's surface undergoes some physical or chemical alteration. When, for instance, the chlorophyll disappears from the leaves in autumn, the green

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[16] Hilbert (1987) p. 27

color in daylight fades away, and is replaced with brilliant shades of yellow, orange, or red in daylight.

This systematic correlation between observational conditions and colors perceived by a given observer is crucial, because it explains why colors play an essential role in object recognition. Given that natural observational conditions and visual systems are pretty stable, a change in color is very often an indication that some physical or chemical change occurred in the colored object. The ripening of lots of fruit, for example, is easily traceable through the progressive color changes which characterize the ripening process. When a color change is perceived by the same observer in the same circumstances, it necessarily corresponds to an *internal color change*, because it implies some physical or chemical change in the object. When a color change is induced only by some change in the observational circumstances or in the observer's visual system, it corresponds to an external color change, because it does not imply some physical or chemical change in the object.

I therefore propose a distinction between color$_1$ and color$_2$: Objects have many different colors$_1$. Some colors$_1$ are detected by the human visual system,[17] whereas other colors$_1$ can be detected by non-human visual systems. A given perceiver in given circumstances will be able to perceive only one color$_1$ of a given uniform surface. However, variations of circumstances can enable consecutive perceptions of different colors$_1$ of the same uniform surface.

On the other hand, objects have only one color$_2$ at a time. The color$_2$ of a uniform surface can be identified with the set of colors$_1$ of the uniform surface. Colors$_2$ are not directly detected by human and non-human color vision systems. Color$_2$ changes can, however, be noticeable though changes of colors$_1$. According to the physicalist proposal in §5, this distinction can be reformulated the following way :

(1) Two surfaces have the same color$_1$ iff they have the same reflectance defined over the same wavelength intervals.

(2) Two surfaces have the same color$_2$ iff all their colors$_1$ are the same, *i.e.* for any illuminant I they reflect the same proportion of I.

Given the distinction between color$_1$ and color$_2$, we can now solve Hardin's problem by saying that if two objects are perceived to match in daylight, they both have the same color$_1$. However, if a change in light reveals some differences in color$_1$ between the two specimens, we must conclude that they do not have the same color$_2$.

Colors$_2$ play a major role in our grasp of reality, because they directly inform us about chemical or physical changes of the colored objects. Unlike differences in colors$_1$, differences in colors$_2$ are always related to some physical differences. In addition, the notion of color$_2$ enables us to explain why optimal color perception is not restricted to a determinate set of standard observational conditions. Metamerism illustrates this point well. Surfaces that have different spectral reflectances but match visually under a given illuminant for a given observer are said to be metamers for that illuminant and that observer. Given their different spectral differences, metamers under a given illuminant will not appear to match under some other illuminant. For most observers and activities, color comparisons are done in some white light (daylight or artificial light). However, for particular laboratory or industrial purposes the relevant illuminant may be composed of different bands of wavelengths. For example, metameric inks, which match in "normal" light conditions, can be used in security applications. Using this technique, a printer can conceal a word, message or image, which is

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[17] Differences in human color vision will not be discussed here (see above, § 3).

invisible to the human eye until the lighting conditions change. The same technique is also used in bank note printing to prevent counterfeiting. Such examples show that to distinguish different colors$_2$, it is sometimes necessary to exploit very particular observational conditions. But this fact is directly explained by the very definition of color$_2$ I offered. Given that color$_2$ of a given specimen is identified with its set of colors$_1$ and that a given observer perceives only one color$_1$ of a given specimen at one moment, variations of circumstances can be necessary to differentiate the colors$_2$ of two specimens. A difference in color$_1$ of two specimens under identical observational conditions implies that the specimens don't share the same set of colors$_1$, and hence don't have the same color$_2$. Finally, a difference in color$_2$ allows us conclude to the existence of some differences in physical or chemical properties of the two specimens.[18]

8. Forgotten colors: bubbles, shells, feathers, compact discs, butterflies and much more

To assert that a uniform surface has a multiplicity of simultaneous colors may seem odd because in most cases we are only able to see one color at a time. However color phenomena are much more varied than is often suggested in philosophical articles and some colored surfaces deserve more attention. As its etymology suggests, "iridescent"[19] surfaces exhibit many simultaneous colors, seeming to shimmer and change as the viewing angle changes. Iridescence is found in many natural and man-made objects such as shells, birds' feathers, insects, compact discs, soap bubbles, and fabrics. Iridescent colors are produced by an object's surface structure, rather than by incorporated pigment molecules; they are often referred to as "structural" or "interference" colors.

Although some shells and artifacts, like compact discs and soap bubbles, exhibit a rainbow-like color spectrum, their surfaces appear to be homogeneous in the sense that all the surface's parts share the exact same physical properties. Non-iridescent multicolored surfaces, on the other hand, are not homogeneous because color boundaries are perceived as physical discontinuities. If you consider, for example, a multicolored beach ball (figure 1), each different colored area is perceived as a different physical part of the ball, whereas variations of color on a soap bubble (figure 2) don't delineate different physical parts of the bubble.

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[18] Austen Clark has suggested to me that I should maybe describe color$_2$ as a superficial physical property of the object rather as a chromatic property. I think his suggestion is insightful, because color$_2$, unlike color$_{1,}$ is never directly perceived. I've chosen to keep the term "color$_2$" to express this distinction, because as expressed for example hereafter by Armstrong, the kind of surface constancy involved in chromatic perception despite change of apparent colors has been often identified with color constancy: "Now consider a coloured surface such as a piece of cloth with fast dye which is subjected to different sorts of illumination. We often say that it presents a different appearance under the different illuminations. This seems misleading. In a *standing sense* the colour does not change. But *in a transient sense* it really does change colour". (D. M. Armstrong 1987, in A. Byrne & Hilbert, D. R., 1997, vol. 1, p. 45, n.6)

As suggested by Clark, we should probably revise this terminology and restrict expressions like "chromatic perception" and "color constancy" to properties which are transient in Armstrong's sense and use some other expressions to refer to the superficial properties which can be tracked down though color variations.

[19] From the Greek *iris*, *iridos*, rainbow or iris plant (Merriam-Webster Dictionary)

Figure 1. A multicolored beach ball.

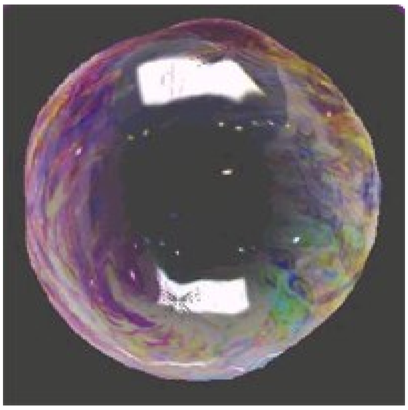

Figure 2. A soap bubble.

The distinction between color$_1$ and color$_2$ captures this difference very well. The various colors$_1$ observable on a beach ball in normal conditions, as in figure 1, are directly related to different colors$_2$, because they correspond to differences in the physical properties of the ball's surface. In contrast, the differences in colors$_1$ exhibited by a soap bubble are not related to differences in color$_2$. Color$_1$ differences on the bubble's surface are caused by thin micro-layered structures reflecting different light wavelengths, depending on the viewing angle and their position to the light source. Each point of the bubble's surface can then appear to be of different color without any change in the physical properties of its surface. Unlike non-iridescent uniform surfaces, a soap bubble exhibits simultaneous colors$_1$ that can be directly observed through changes in viewing angle.

To go back to our initial question, we can conclude that lemons are yellow, blood red and snow white. However this is not the whole story, because contrary to what is commonly assumed, lemons are not exclusively yellow. Lemons, like all colored objects, have many different objective colors that exist independently of any observer or any special observational circumstances. The high variability of color appearances can therefore be accounted for by the great variety of objective colors and not by the fact that color properties are relational, subjective or somehow unreal.

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