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A LIGHT THEORY OF COLOR

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ABSTRACT. Traditional theories locate color in primary qualities of objects, in dispositional properties of objects, in visual fields, or nowhere. In contrast, we argue that color is located in properties of light. More specifically, light is red iff there is a property *P* of the light that typically interacts with normal human perceivers to give the sensation of red. This is an error theory, because objects and visual fields that appear red are not really red, since they lack the properties that make light red. We show how this light theory solves or avoids problems that afflict its competitors.

Traditional theories of color fall into four main groups. The first group locates color in primary qualities of objects, the second in dispositional properties of objects, and the third in visual fields. Problems with these accounts lead to a fourth approach, eliminativism, which denies that color can be found anywhere. In contrast with all of these views, we will argue that color should be located in properties of light.

1. THE PRIMARY QUALITY VIEW

The primary quality view is best presented by Frank Jackson, who writes,

> [object] *O* is red at [time] *t* iff there is a property of *P* of *O* at *t* that typically interacts with normal human perceivers in normal circumstances to make something that has it look red in the right way for that experience to count as the presentation of *P* in that object. (1998, p. 97)

This view explains why a red apple does not change color in green light or in no light or if everyone goes colorblind.

Many objections have been raised against this primary quality view, but it is amazingly resilient. Still, one major problem remains:

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There seems to be no unified property of objects that causes white light to be reflected as red light or that causes objects to look red to human perceivers (cf. Hardin, 1988, pp. 2 ff.). Similarly for more specific shades of red. Jackson admits that his theory would be "in trouble" if the property *P* to which his analysis refers were too disjunctive, because "excessively disjunctive properties cannot be causes" (1998, p. 106). In response, Jackson refers to a triple of integrated reflectances, which he describes as "the result of taking the reflectance – that is, certain proportions of reflected light to incident light – over three band-widths, scaling, then summing" (1998, p. 109). However, reflectances are dispositions to reflect light in certain proportions (cf. Hilbert, 1987, p. 25), so they are not primary qualities of objects. These dispositions do have bases in primary qualities, but specifying a reflectance as a disposition does not show that its base is unified enough to count as a single cause or primary quality. Consequently, reflectances cannot solve the problem of unity for primary quality theories.

Moreover, even if some unified primary quality did account for colors of objects that reflect, not only objects that reflect seem to be colored. Some filaments appear black when the electricity is off but look red when just enough electricity runs through them. Perceivers of such glowing filaments would say (correctly) that they see something red. The primary qualities that make such a black filament glow red are very different from the primary qualities that make a shirt look red in sunlight. Since something is red in both cases, being red should not be identified with primary qualities as in Jackson's theory. Similar points could be made about glowing gases (in fluorescent bulbs), fireflies, flames, holograms, rainbows, sunsets, and the sky when it appears blue.

2. DISPOSITIONAL VIEWS

These problems are supposed to be solved by dispositional views. Even if red objects do not have any common and peculiar primary qualities, red objects can still share a disposition to cause certain kinds of experiences in perceivers. Red light sources also have dispositions to cause such experiences. This similarity makes it natural to suppose that color is a dispositional property of objects and of light sources to cause relevant experiences. Johnston (1992) develops a subtle version of this approach with a careful analysis of dispositions.

Still, a major objection remains: These dispositions are not causes in the ways that colors are. Even if some dispositions are causes, which is questionable, the dispositions that these dispositionalists identify with colors do not play the same causal roles as colors. When I take a picture of a red shirt, the color from the shirt causes a chemical change in the film. The cause of this effect on the film cannot be a disposition of the shirt to cause experiences in perceivers, since these effects on film are independent of perceivers. In this way, there's more to color than meets the eye.

Dispositionalists might respond that colors aren't causes, but the bases of such dispositions can cause changes in film. However, a red flame can cause the same chemical change in film that a red shirt causes. We already argued that a red shirt and a red flame share no unified primary quality. Similarly for red sunsets. Thus, there is no unified base of such dispositions that could cause what colors cause.

What does cause the change in the film as well as the experiences is the red light reflected by the shirt, so dispositionalists might modify their view and analyze the color red as a disposition to reflect red light (which is distinct from the disposition to affect perceivers or film). However, even if colors of objects can be analyzed in this way, this disposition to reflect red light cannot be what makes light sources red. One simple reason is that light sources like flames emit light without reflecting light.

To avoid this problem, dispositionalists might try to analyze a color as a broader disposition, such as a disposition to either reflect or emit (or refract or scatter) colored light. Unfortunately, this disjunction seems excessive in a different way, and this account also raises new problems. Consider a black filament with a disposition to glow red when just enough electricity runs through it. While the electricity is off, the filament still has this disposition. Thus, if a disposition to emit red light made something red, the filament would be red even while the electricity is off. However, the filament looks black at that time, and it cannot be black and red all over at the same time from the same angle. Besides, when the electricity is off, the filament does not look red. It looks red only while the disposition to emit red light is actually manifested. Hence, the red color of the glowing filament cannot be analyzed as a disposition to emit red light or even as the broader disposition to either reflect or emit (or refract or scatter) colored light. Dispositionalists cite dispositions to explain why red shirts are red even in dark closets, but they forget that light sources like filaments are not red when they are off. (Similarly, refractors like clear prisms are not red when they are in dark closets, even if they look red from a certain angle when struck by white light. And the sky is not the same shade of blue at night, although at that time it retains a disposition to appear that shade during the day.)

The most serious problem of all is that light itself can correctly be called red, but red light does not have to disposition to either emit or reflect or refract or scatter red light. It just *is* red light. Thus, even if this broad dispositional theory did work for objects, it still could not handle the colors of glowing filaments, prisms, skies, or light. This dispositional theory, like the primary quality theory, survives only on a small diet of examples.

3. SUBJECTIVE ERROR THEORIES

The third traditional account of color is an error theory, for it implies that objects do not really have colors (as either primary qualities or dispositional properties), even though we commonly believe that objects have colors, so our common beliefs are false. Boghossian and Velleman (1989) develop a subjective version in which colors are internal properties of perceivers's visual fields. Our errors arise when we project these internal properties onto external objects, thereby producing the common but false beliefs that objects are colored.

Although dispositional theories are sometimes labeled subjective, we will call a theory subjective only if it locates colors completely inside the subject's mind. Subjective theories need not all be error theories, since idealists, such as Berkeley, can adopt a subjective approach without ascribing errors.

Such subjective theories solve some problems for competitors, especially why colors are ascribed to after-images. However, subjective theories have their own implausible implications, such as that, if all perceivers went colorblind, then there would be no colors. Red shirts, red flames, and red sunsets would still have the same effects on film (and on plants), but subjective theorists could not adequately explain why. To adequately explain the similarities among these effects, we need to classify the light coming from the shirts, flames, and sunsets as red.

Subjective theories also have trouble explaining how we teach and learn color terms and concepts (see Stroud, 2000; Ellis, unpublished). Normally, teachers point and say, "That's red", "That's green, not red", and so on. They are not pointing to their own visual fields. To do that would be either impossible or useless, because the learner cannot see the teacher's internal visual field. There are ways to teach internal states by analogy and behavior, but they are not used to teach colors.

These objections from causation and learning also apply to eliminativism (as in Hardin, 1988, p. 112), since eliminativists cannot cite colors as causes or explain what color teachers point to. However, it must be admitted that these objections, like the others that we raised for other theories, are not conclusive. Defenders of each approach can respond by making well-known moves with varying degrees of plausibility. We will not repeat the dialect here, since our main goal in raising these problems is not to refute these views but only to motivate an alternative that provides a natural solution to these problems and more. This alternative has origins at least as far back as Newton, but we hope to develop it in a somewhat novel way.

4. THE LIGHT THEORY

Our theory claims simply that colors are properties of light, whether that light is emitted from a source, reflected by an object, refracted in a sunset, or scattered in the sky. That is why we call it a light theory of color. Colors are then located in the causal chain between objects and visual fields, insofar as the properties of objects affect properties of reflected light which in turn affects the retina, brain, and visual field (which is in the mind, wherever that is). So our theory can also be labeled an intermediate view of color. In one way, this account is closer to primary quality views, because light is an objective, physical phenomenon outside our minds. Still, this new theory is an error theory about colors of objects, because it implies that an external object, such as a shirt, does not really have any color, since objects lack the properties that make light have colors. In that sense, this theory can also be seen as an objective error theory of color.

However it gets described, this view adapts Jackson's form of definition:

Light is red at *t* iff there is a property *P* of the light at *t* that typically interacts with normal human perceivers in normal circumstances to give the sensation of red.

Similarly for the other colors and specific shades of colors.

This analysis might seem circular, because it refers to red at its end. However, the sensation of red is not itself red, as we will see. Instead, the sensation of red is just the characteristic mental representation of something that is red. More technically, to give the sensation of red is just "to make something look red in the right way for the experience to count as a presentation of *P* in light" (as in Jackson, 1998, p. 97). This avoids any circularity that is vicious.

The content of the analysis for a particular color comes with property *P*. Science reveals what property *P* is. Thus, contrary to the principle of revelation (in Johnston, 1992, p. 223), we cannot know all about a color just by looking. This is another way in which there's more to color than meets the eye.

What science discovers turns out to be complex, but *P* is still a property of light rather than of objects. Furthermore, this property of light is more unified than the primary properties of reflectors, refractors, emitters, and scatterers that are supposed to give those things certain colors. Consider a shirt and a flame that look the same shade of red. They send out red light by very different processes. Nonetheless, the light from the shirt and the light from the flame can still affect a digital camera in the same way, as they do when the digital camera records the same one out of the millions of colors that it distinguishes. Moreover, the light from the shirt and the light from the flame cause this effect directly and by the same physical process. Such causal patterns are evidence that the light from the shirt and the light from the flame share some unified property that makes them both red and explains their effects. If the light from the shirt and the light from the flame had nothing in common that made them red, then their common effects would be purely accidental. This seems unlikely, especially when one considers that the light from the shirt and the light from the flame also have similar effects on our eyes and on our experiences, that their effects are similar to those of red light from a sunset or a prism, etc. And the same points apply to the other colors. This all together suggests that the property of light that makes it a certain color is unified in some way.

But how? It is hard to specify exactly what the relevant properties of light are, but science has revealed much about what they are not. Property *P* is not a single wavelength. Light with a single wavelength can have color, but light with mixtures of wavelengths can also count as red, green, or other colors, when its effects on eyes and film are similar enough to that of the single wavelength light.

It is also not only wavelengths that matter to color. "The spectral profile of a chocolate bar closely resembles that of an orange, but, under the same lighting conditions, the light reflected from the chocolate bar is of much lower intensity" (Hardin, 1990, p. 559; cf. 1988, p. 141). Thus, if color were defined by wavelengths alone, the light from the chocolate bar would be orange. It isn't. But this hardly refutes the light theory of color. All it shows that colors are functions of intensity in addition to patterns of wavelengths. This reference to intensity is also needed to handle the Bezold-Brueke hue shift: "Color samples will look more reddish or greenish at lower light levels, and more yellowish or bluish at higher light levels" (Hardin, 1988, p. 45). Light theorists can say that the light coming off a color sample changes hue as its intensity increases or decreases, because light with those patterns of wavelengths plus intensities "typically interacts with normal human perceivers in normal circumstances to give" different sensations. It is not clear exactly how to build intensity into accounts of colors, but nothing debars light theorists from considering intensities in addition to wavelengths when identifying patterns of light as colors.

Still, property *P* does not involve *all* features of light. As Hardin points out, "for most perceptible light stimuli, there exist indefinitely many other stimuli, each with a physically distinct wavelength combination, that will evoke precisely the same perceived color" (Hardin, 1990, p. 556). Why? Because our eyes usually include only three types of cones, each of which is sensitive to a limited band of wavelengths and to varying degrees within its band, and the signal from these cones that reaches the brain depends only on the ratios of the excitations. This mechanism allows "massive information loss" (Hardin, 1990, p. 556; cf. 1988, p. 26). When light stimuli differ in ways that these receptors do not register, the different kinds of light will look the same color. However, that does not make the light theory excessively disjunctive, since the differences between these batches of light need not be differences in color. Just as a single element can contain many isotopes that differ in the number of neutrons as long as these isotopes contain the same number of protons, so batches of red light can differ in inessential ways as long as they are similar in the respects that constitute colors. What these scientific findings show is, at most, that not all properties of light matter to color.

More experiments suggest more complications, such as that the relative rather than absolute intensities within the three wavebands constitute colors. However, there are limits to how far a light theory should go to accommodate appearances. In particular, since the light coming off a color chip is not affected by its surroundings, a color in light should not be defined by a function of its surroundings. Simultaneous contrast is then an illusion. As Hardin points out, "two squares cut from the same piece of colored paper can look very different from one another when placed on backgrounds that differ from each other in color" (1990, p. 558; cf. 1988, p. 49). However, all this shows is that the light from the squares *appears* different colors in different surroundings. That should be no more surprising than that two pans of water at the same temperature feel different depending on the surrounding temperature. This does not show that heat should be analyzed as a function of its surroundings. Analogously, the fact that the same light from the same square looks different in different surroundings also does not show that the color is not constant or that the color is not a function of some property of the light itself. Surroundings must be mentioned to explain apparent colors, but that is not what the light theory is trying to do. The light theory is an account of real colors, so surroundings need not enter into the property *P* that constitutes a color.

Whatever it is, the property *P* is an objective feature of the external world, even though it is identified by reference to perceivers. Light has properties on many continua, and only reactions of perceivers explain why we group together certain kinds of light under certain color names. Among normal perceivers, some distinguish more colors than others or draw lines at different points. A light theorist could hold that two batches of light are different colors if any perceivers can distinguish them under any conditions. More finely, a light theorist could say that each different pattern of light is a different color, even if the best perceivers cannot detect all the differences. (Compare Hilbert, 1987, p. 99.) Either way, different people will group different shades under different general color names, so we need not agree on which specific shades count as red, for example. If one wants to analyze how normal perceivers classify colors, one must refer to reactions of those perceivers. But there still might also be more objective classifications determined by the causal powers of different kinds of light. Or there might not. The question of where to draw lines between different groups of wavelengths and intensities so as to define particular colors is separate from the question of whether colors are properties of light as opposed to objects or visual fields. Even if the lines between colors were not objective, that would not keep colors from being properties of light.

5. THE OBJECTIVE ERROR THEORY

Since the light theory is an error theory about colors in objects, it should not be expected to specify conditions when an object is (really) red, but a light theorist can still explain appearances: An object looks red if and only if it reflects or tends to reflect white light as red light. A light source looks red if and only if it emits red light. Similarly for refractors and scatterers of light.

Objective error theorists still need to explain why so many smart people make the mistake of believing that objects and light sources are red. They also need to explain why so many smart people say and believe that after-images in our visual fields are red even when no light is present. Both mistakes can be explained by analogy with an old example from Aristotle. What is primarily healthy is an organism, but we call certain foods healthy because we believe that they tend to cause health in an organism, and we call certain urine healthy because we see it as a sign of health in an organism. Analogously, what is primarily colored is light, but we call objects (as well as sources, refractors, and scatterers of light) colored because they tend to cause colored light, and we call after-images and dreams colored because they are or resemble signs of colored light (since similar properties of visual fields usually result from colored light).

This account might seem to remove any error, but it does not. Objects can have dispositions to reflect red light, as well as primary qualities that are bases for those dispositions. That explains why people think that those objects are red, but it is still not accurate to call the object itself red, any more than it is accurate to call a shriveled, dead raisin healthy. This is obvious in the case of a raisin, so nobody believes that a raison is healthy in the same way that an organism is healthy. However, people do believe that objects have colors in the same way as light. The explanation for this belief seems to be that the red light that makes the object or source look red lies straight between the perceiver's eyes and the object or source, and the light is not visible in the intervening space. This orientation makes it natural for the perceiver to believe that the object or source is itself red. Nonetheless, this belief is still false, because only the light is really red, since only the light has the property P that constitutes the color red. Smells are different in this respect. The smell of cheese is detected when small particles from the cheese enter one's nose. The cheese itself retains some of the same kinds of particles. In contrast, a red shirt does not itself have any of the properties of light that we detect when red light enters our eyes. Thus, we can speak accurately about the color *from* objects and sources but not about the color *of* objects and sources.

Similarly, even if some parts of a visual field are signs of color, they are not strictly colored. Subjective theorists claim that after-images contain colors. However, after-images are simply illusions and are not real instances of color. It is possible to stimulate an area of the brain to produce a sweet sensation on the tongue without putting anything in the mouth. In this case, the sensation of sweetness is an illusion caused by a trick. There is no real sweetness to be tasted. Analogously, in the case of after-images, there is no color to be perceived. Colors can exist only where light is present. Since after-images persist in the absence of light and do not have the properties that make light colored, the after-images cannot be colored. The reason why we call them colored is that they appear so similar to the effects that colored light normally has on our visual fields. Thus, the light theory can explain why smart people form the beliefs that they do, even though these beliefs are errors.

6. SOME APPLICATIONS

This light theory can also easily explain why we say, "This hat is really green even though it looks blue under this purple light". The light on the hat is purple, and the light coming from the hat is blue, but we can call the hat green, because we falsely believe that the color resides in the hat, and the hat has not changed. Similarly, we can call our shirt red even when it is in a closed closet with no light at all, because we falsely believe that the color resides in the shirt, and the shirt has not changed. In fact, there is no color at all without light. The hat is not green and the shirt is not red, even if we call them green and red because they have a disposition to reflect white light as green light and red light, respectively.

The light theory does not imply that "objects will change their color with every change in the illumination" (Hilbert, 1987, p. 24). Objects do not change color, because objects do not have color. The light from objects does change color as the incoming illumination changes in some ways, but there is nothing strange about that.

The colors in light would not change if our eyes or brains or visual fields changed; nor would all colors cease to exist if all perceivers went colorblind (contrary to subjective theories). The light theory does imply, however, that the colors from objects would change if objects began to reflect different kinds of light or if (somehow?) light changed so that it had different properties when it came off the same objects. These implications seem plausible, because, for example, they would explain variations in the effects on film.

In addition to color changes, the light theory also needs to explain so-called color constancy, which is "the familiar phenomenon that apparent colors of objects are relatively independent of the character of the illumination under which they are viewed" (Hilbert, 1987, p. 25). For example, a rose (or grass) at noon and at twilight can appear the same shade of red (or green), even though the light coming off the rose (or grass) is very different at the different times. These apparent colors actually seem quite different to many people, but many other people report that the rose (or grass) looks the same shade at the different times. In any case, even if the apparent color does seem constant, this appearance can be explained within the light theory. Although many properties of the reflected light vary from noon to twilight, the properties that constitute the color green in the light from the grass still might remain constant if the property *P* of light that constitutes that color is a ratio of intensities within different wavebands (Hilbert, 1987, pp. 70–71). That comparative property can remain constant even if the intensity within each waveband changes, which would explain why the color does not change with such changes in illumination. This explanation depends on details of property *P*, but, if those details are disputed, then light theorists can make a different move. In so-called color constancy, what remain constant are "apparent colors", not real colors. Consequently, a light theorist can see so-called color constancy as an illusion, in which real colors do change while they appear to remain constant. This appearance of constancy might be created by an automatic prediction of what color the object would appear under another illumination that is seen as more normal. Such an illusion has survival value, because it enables perceivers to pick out the same objects under different illuminations. Thus, whether or not real colors remain constant under changing light, it is easy to understand why we would evolve so that objects appear to have constant colors.

7. TRICKIER CASES

A trickier case is metamerism. Some pairs of objects both appear green in daylight, but incandescent light makes one appear green and the other appear brown (or darkened orange) (Hardin, 1988, pp. 46–47). The scientific explanation is that the surfaces select different wavelengths from the incoming lights, which differ in some areas of wavelength. This account fits well with the light theory of color, which implies that, when the object appears different colors in different kinds of light, that is because the reflected light really has different colors in those situations, even thought the objects themselves have neither color.

Another problematic example (discussed by Johnston, 1992, p. 247) is a magazine with a patch that looks red from normal viewing distance, but closer inspection reveals that the patch is made up of small dots that look magenta and yellow. Is the patch red or is it yellow and magenta (but not red)? Neither, according to the light theory, since no object is really colored. The light reflected from the patch is a mixture of magenta and yellow. If viewed from a distance with binoculars, the small dots that look magenta and yellow will be distinguishable, so the bits of yellow and magenta light do not interfere with each other. One small cylinder of light is yellow, and the one next to it is magenta, even though the combination affects our eyes in the same way as if the light were uniformly red, which is why it appears red. Is any light in this case really red? That depends. If we focus on areas of light the size of the small dots in the magazine, none of these dots of light is red. Each dot-sized area is either yellow or magenta. However, we could focus instead on larger areas of light, the size of the whole patch, containing many of the dots. This larger area includes a pattern of wavelengths and intensities "that typically interacts with normal human perceivers in normal circumstances to give the sensation of red", so this larger area of light fits the definition of red in the light theory. This red area of light is made up of smaller areas that are not red, because the patterns of wavelengths and intensities inside those dot-sized areas do not "typically interact with normal human perceivers in normal circumstances to give the sensation of red". It might be surprising that this red light consists of only non-red parts, but that is no problem for the light theory.

This flexibility regarding area sizes also helps to explain how white can be a color. White light consists of many wavelengths at varying intensities, but we can still say that an area of light is white when light of that pattern "typically interacts with normal human perceivers in normal circumstances to give the sensation of" white. Similarly for shades of gray.

Black is more difficult, since no light is black, despite the misnomer "black light". Objects and night skies are not really black either, but they appear black when relatively little light comes from them into our eyes. Many people think of black as the absence of light, but that is inaccurate. When no light at all enters our eyes, the apparent color is a dark gray that is sometimes called "brain gray". Objects appear black only in contrast with lighter surroundings (Hardin, 1988, pp. 23–24). In any case, the appearance of black is caused by a property of light, namely, its relative lack of intensity in the areas that look black. That does not mean that every area with relatively little light is black. Nothing is really black, neither objects nor night skies nor light, even when they appear black. Is black even a color? Black can be viewed as an achromatic color or as the absence of color. Either way, the light theory can cite relative properties of light to explain why some things appear black even though they are not.

A related case is brown, which some theorists "take . . . to *be* a blackened orange" (Hardin, 1988, p. 141). If brown appearances always result from simultaneous contrast with surroundings, then nothing is really brown, according to light theorists. The same reasoning might also apply to olive, navy blue, and other colors in which black plays an essential role. Such apparent colors are illusions in ways that the colors in the visible spectrum are not.

8. RELATIONS AMONG COLORS

Relations among colors can also be handled by the light theory of color. Distinct colors are often supposed to exclude each other in the sense that the same object cannot be both red all over and green all over at the same time. Actually a flat hologram can appear red all over and green all over at the same time but from different angles. Primary quality and dispositional theories must say that such objects are different colors from different angles. The light theory has a more natural explanation: The object itself has no color, but different colors of light are reflected in different directions, so they can be viewed from different angles. Still, the property that makes light red is incompatible with the property that makes light green (because light cannot have both properties at once). That explains why the same object cannot appear both red all over and green all over at the same time from the same angle.

Colors can also look more or less similar. For example, red appears more like orange than like blue. Some simple cases can be explained easily on the light theory, because the wavelength of light that is red is closer to the wavelength of light that is orange than to the wavelength of light that is blue. The color spectrum shows this. This explanation applies directly only to single wavelengths at a given intensity, but it can be extended to mixtures of wavelengths and intensities that are also red, orange, and blue. A red mixture looks like the red wavelength, which is closer to the orange wavelength, which looks like the orange mixture. That explains why the red mixture looks closer to the orange mixture. The red mixture looks less like the blue mixture, because the blue mixture looks like the blue wavelength, which is farther from the red wavelength, which looks like the red mixture. Although this indirect explanation is complex, the primary quality view has even more trouble explaining such relations among colors, because the primary qualities of red sunsets are closer to the primary qualities of blue skies than to the primary qualities of oranges.

Other cases are tougher for the light theory. Many (though not all) perceivers report that red looks more like blue than like green, even though the red wavelength is closer on the visual spectrum to the green wavelength than to the blue wavelength. Moreover, some objects appear red-blue, but nothing appears red-green. The explanation of both cases lies in our brain, since we detect red and green by means of opposite states (excitation and inhibition) of chromatically opponent cells (Hardin, 1988, p. 52). Nonetheless, light theorists can still say that the red wavelength is closer to the green wavelength than to the blue wavelength, even if our neural system makes red light look more like blue light than like green light. The structure of our visual system also explains why many people report perceiving a larger difference between green and yellow than between red and orange, even though the difference between the wavelengths of green and yellow light is approximately equal to the difference between the wavelengths of red and orange light. These are just more illusions, and this account can be extended to mixtures of wavelengths and intensities by the indirect method outlined before. The structure of our perceptual systems then explains why perceived similarities and differences among colors do not always match the objective similarities and difference among colors in light.

9. COMPARING COMPETITORS

In addition to handling such tricky phenomena, the light theory also solves or avoids the problems that afflict its competitors. Primary quality theories are often criticized for being excessively disjunctive. We argued that there is unity in the properties of light that make light have certain colors. But then we saw that humans sometimes react similarly to different patterns of light, as in the case of red light versus magenta and yellow dots of light. This requires some disjunction in "property *P* of the light that typically interacts with normal human perceivers in normal circumstances to give the sensation of red". Nonetheless, this property still avoids the excessive disjunctions that plague traditional primary quality theories. Such primary quality theories need disjunctions in property *P* to analyze the same color in objects (like shirts), light sources (like flames), refractors (like sunsets), and scatterers (like the sky). In contrast, the light theory can simply point out that the same kind of light comes to our eyes from different kinds of origins.

We also saw that some dispositional theories have trouble with colors as causes. In contrast, there is no mystery about how non-dispositional properties of light can cause physical effects on digital cameras as well as mental effects on perceivers. When blue light from paint and blue light from the sky have the same effects on a digital camera, these causal patterns give us reason to ascribe a color to the light from both origins. One could describe such causes without explicit reference to colors by referring only to functions of intensities and wavebands of light, but these redescriptions would be equivalent to colors, according to the light theory. Description aside, the point is that the light theory can easily explain why colors can have physical and mental effects just as other properties of light can.

Other dispositional theories had trouble explaining why we believe that black filaments are not red when the electricity is off, although such filaments still have a disposition to glow red when just enough electricity runs through them. The light theory implies that such filaments are not red when the electricity is off, but we see them as red when electricity runs through them, because then the filaments produce red light. A puzzle remains about why we believe that the filament ceases to be red when the electricity goes off, but a red shirt remains red when the lights go off. The reason why we treat these cases differently might be that we believe that nothing inside the shirt changes, but something (electricity) inside the filament does change. In any case, the light theory implies that the real color in light changes no less when the lights go off than when the electricity goes off, so this puzzle for dispositional theories disappears.

The remaining problem for subjective error theories is learning, because a teacher cannot point to a part of a visual field that the student can see. This problem would not be solved if color were analyzed in terms of retinal excitation or brain states (or by eliminativism). However, if colors are properties of light in the external world, then we can teach color terms and concepts by ostensively referring to the light reflected from objects, even if we falsely believe that we are referring to the objects themselves. Since light is objective, it is public in the way that is needed for teaching and learning by the methods that we use to teach colors.

Critics might object that what color teachers teach does not have the content that the light theory suggests. Children learning color terms are told nothing about properties of light that constitute colors according to the light theory. However, children are also taught the term "water" without being told about hydrogen and oxygen. That simplified pedagogy does not refute the claim that water is H_2O. Analogously, the complexities in property *P* do not show that a color is not identical with that property of light.

A final, common objection to the light theory is that we see the colors that we teach, but we do not see light. Admittedly, we do not see light when it moves perpendicular to our line of sight. However, we should not expect to see anything that has no effect on our eyes. We do see light when it enters our eyes and strikes our retinas. That is the only way in which we need to see light in order for us to see the colors in light.

Overall, the light theory has a lot going for it and plenty of resources to answer some obvious objections. Still, opponents are likely to raise other objections that we have not foreseen, and many details need to be developed. So doubts remain. To dispel those doubts would take much more than a short paper. Here we hope only to have said enough to make the light theory seem interesting and worth pursuing as a new option in the space of possible accounts of color.

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