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Debunking Color Objectivism:

The Anti-Objectivist View of Colors

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Abstract

Colors are part of our everyday experience. But what exactly are colors? Mainstream analytical philosophy often supports color objectivism, that is, the view that colors are properties of material objects (see, e.g., Johnston 1992, Campbell 1993, Jackson 1996, Lewis 1997, Armstrong 1999, Byrne and Hilbert 2003, McLaughlin 2003, Cohen 2009, Allen 2016, Gert 2017). Color objectivism is often alleged to be supported by the phenomenon of color constancy: the colors of objects appear to be roughly the same under various illumination conditions when viewed. This suggests that colors are illumination-independent, perception-independent, intrinsic properties of the objects. However, there are two challenges. First, there is the phenomenon of color variation: under the same illumination, the monochrome surface of an object exhibits different color appearances to the same perceiver, or to different perceivers, or to perceivers from different species. This supports the view that colors are perception-dependent. Second, the color-related sciences, especially the modern physics, do not seem to support color objectivism. Theoretical physicists, who seem to be better equipped to argue for color objectivism due to their grasp of the best physical theories of both matter and light–matter interaction, when commenting on the nature of color, never mention that colors are properties of object. For instance, the theoretical physicist Richard Feynman claims that "[c]olor is a sensation, and the sensation for different colors is different in different circumstances" (2013/1963: Vol. I, Ch. 35).

Accordingly, this dissertation examines whether color objectivism can meet these two challenges, aiming to establish the following main thesis:

(T) The anti-objectivist view of colors: All main versions of color objectivism in their current forms are false.

I classify the main versions of color objectivism into two kinds: reflectance-grounded objectivism and color-disposition-grounded objectivism. According to the former (including reflectance physicalism, microstructure physicalism, color primitivism), colors are intrinsic, reflectance-related properties of physical objects. According to the latter (including color dispositionalism, realizer functionalism and role functionalism), colors are color-disposition-related properties such that the objects having those properties are disposed to look colored to certain perceivers in the relevant viewing conditions. Reflectance-grounded objectivism is claimed to be supported by color constancy, while color-disposition-grounded objectivism is alleged to be backed by color variation. Importantly, both kinds of color objectivism are alleged to be compatible with science.

Strategically, I take reflectance physicalism is as the primary target of the anti-objectivist view of colors. Reflectance physicalism applies reductionist a posteriori physicalism which employs an identity thesis. Reflectance physicalism first establishes its *Color Thesis*: Colors are illumination-independent, mind-independent properties of material objects. It then proposes a view of reflectance: Surface spectral reflectances (SSRs) are illumination-independent, mind-independent, intrinsic surface properties of objects, which are

dispositional properties posited by science. Let's call that the *SSR Thesis*. Given the equivalence of the *Color Thesis* and the *SSR Thesis* within a posteriori physicalism, colors are identical with SSRs. I argue that the *SSR Thesis* is false due to its conflict with science, especially electrodynamics. This implies that without examining the argument for the *Color Thesis*, one knows in advance that the argument is unsound. I then identify the specific mistakes in the premises of this argument, covering topics such as simultaneous color contrast, the nature of color phenomenology, externalist representationalism, whether the color–illumination distinction is perceptually given, the imaginary nature of visual depth, the color membership of black, and whether SSRs are causally efficacious as dispositional properties.

Reflectance physicalism is pivotal in shaping the color debate and can be used to reject other versions of color objectivism. First, reflectance-grounded objectivism is false due to the falsity of the *SSR Thesis*, as the former relies on the latter. Second, the *SSR Thesis*' conflict with electrodynamics suggests that color-disposition-grounded objectivism similarly conflicts with electrodynamics. Importantly, I argue that the conceptual frame of color-disposition-grounded objectivism conflicts with the boundary conditions in electrodynamics.

To examine whether color objectivism meet the challenge from science, I propose that although science is not sufficient to support the scientists' view of color, it is sufficient to reject all main versions of color objectivism in their current forms. Specifically, to respect color science, color objectivism must account for radiant energy (or the reflected light) in terms of the properties of objects in a proper way, where radiant energy represents the objective side of the correlation (established by color science) between physical stimuli and the resulting perceptions. Accordingly, color objectivism must involve the following thesis: The physical properties responsible for light reflection are intrinsic to objects. Let's call it the *Intrinsic Light Reflection Property Thesis* (*ILRP Thesis*). I argue that this thesis conflicts with the color related sciences, especially electrodynamics. Importantly, the argument from the conceptual conflict with electrodynamics (see Section 8.3) which applies to all main versions of color objectivism, deserves special emphasis. The argument shows that the boundary conditions in electrodynamics conceptually imply that the primary physical factors responsible for light reflection are contextual and not intrinsic to objects, which conceptually conflicts with the *ILRP Thesis*. Thus, I conclude that all main versions of color objectivism are false because they conflict with science.

This strongly suggests that color objectivism cannot adequately respond to the challenge from color phenomenology, which requires reconciling the tension between color constancy and color variation. Specifically, I argue that the support from color constancy for reflectance-grounded objectivism and the support from color variation for color-disposition-grounded objectivism are highly problematic.

To sum up, the dissertation establishes the anti-objectivist view of colors by rejecting all main versions of color objectivism in their current forms. Importantly, the anti-objectivist view of colors, as a negative thesis, is typically understood as following from certain positive theses in anti-objectivist color theories, such as color subjectivism. However, in the dissertation, the anti-objectivist view of colors is established independently of any metaphysical assumptions about colors. Consequently, even if these positive theses fail, color objectivism still cannot be correct.

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Introduction: Debunking Color Objectivism

The investigator of nature cannot be required to be a philosopher, but it is expected that he should so far have attained the habit of philosophizing, as to distinguish himself essentially from the world, in order to associate himself with it again in a higher sense. He should form to himself a method in accordance with observation, but he should take heed not to reduce observation to mere notion, to substitute words for this notion, and to use and deal with these words as if they were things.

—Goethe, *Theory of Colors*

1.1 What are Colors?

As a metaphysical inquiry, to ask "What are colors?" is to investigate the nature of colors. Despite its simplicity, the question is far from easy to answer. There are two challenges. The first arises from the relation between the metaphysics of color and color as a phenomenon. The second pertains to the relation between the metaphysics of color and science. In what follows, I present two observations to highlight these two challenges, respectively.

The first observation is a phenomenological one. To investigate the nature of color, the natural starting point is phenomenology.[1] Color phenomenology involves carefully observing and describing the various color phenomena. Given sufficient familiarity with the details of the phenomena, one can tentatively draw some metaphysical conclusions and formulate a color theory. However, the richness and abundance of color phenomena pose many difficulties, notably different color phenomena seem to support two contrary conclusions. Some strongly suggest that colors are perception-independent features of objects, while others point to colors being perception-dependent. "Perception-dependence" means that the properties are not inherent to the objects, as they appear to be, but rather properties of the way the objects are perceived by observers, where the "properties of the way the objects are perceived" do not essentially depend on the objects, like being appetizing.

On the one hand, the phenomenon of color constancy (the observation that the colors of objects appear to be roughly the same under various illumination conditions when viewed)

[1] Regardless of one's visual ability, anyone with a grasp of how to use color language and with a capacity for reasoning can engage in the philosophical discussion of color. It might well be the case that a congenitally blind thinker has a good understanding of the nature of color. But a blind thinker still needs the phenomenological descriptions of color experience from sighted people. Thus, it is fair to assume that color phenomenology is a natural starting point for the metaphysics of color.

suggests that colors are illumination-independent, perception-independent, intrinsic features of the objects. For instance, a wall appears to exhibit (roughly) the same degree of whiteness when viewed at different times during the daytime, suggesting that its whiteness is an intrinsic feature of the wall.

One the other hand, the ubiquitous phenomenon of color variation supports the quite contrary view that colors are perception-dependent. Color variation means that, under the same illumination, the monochrome surface of an object exhibits different color appearances to the same perceiver, or to different perceivers, or to perceivers from different species. The Figures 1.1, 1.2 and 1.3 are cases of color variation at the intra-personal, inter-personal and inter-species level, respectively.

Figure 1.1: Color variation at the intra-personal level: The background is light blue on the left side and dark blue on the right side, while the horizonal bar framed by it appears to be dark blue on the left side and light blue on the right side. But when one screens off the background, the horizontal bar appears to have uniform blueness.

Figure 1.2: Color variation at the inter-personal level: In 2015, a photo went viral on the Internet. Viewers of the photo disagreed regarding whether the dress is black and blue or white and gold. This disagreement shows that, under the same illumination conditions, an object can exhibit different color appearances to different normal human perceivers.

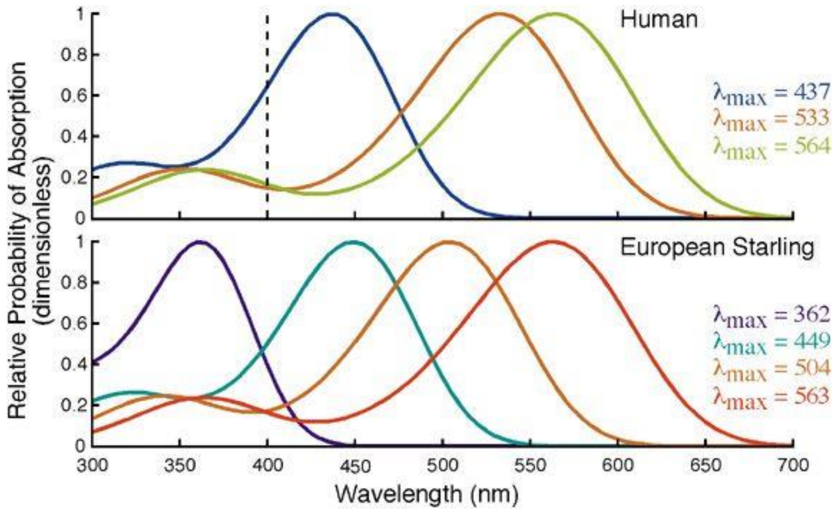

Figure 1.3: Color variation at the inter-species level: A comparison between human and European Starling regarding the relative spectral sensitivities (or relative probabilities of absorption) of the cone cells shows that, given the same incoming light, different visual systems are sensitive to different numbers of wavelength intervals with different extreme points and different curve patterns. This suggests that, in all likelihood, for an object under the same illumination conditions, some animals' color experience is different from that of humans.

In sum, it is unclear that color phenomenology favors a certain color theory. Hence, to investigate the nature of color, the first challenge is that, whatever a color theory might be, it must accommodate the tension between these two kinds of color phenomena.

The second observation is a sociological one. To investigate the nature of color, it is crucial to make sense of the relation between the metaphysics of color and the color-related sciences. However, there is a conflict between scientists' view of color and the mainstream view of color among contemporary analytical philosophers. It is fair to claim that the mainstream view among philosophers is color objectivism: colors are properties of material objects. A great many philosophers take it as the starting point for further theorizing. For instance, in a paper about color, the philosopher David Lewis claims:

> It won't do to say that colours do not exist; or that we are unable to detect them; or that they never are properties of physical things; or that they go away when things are unilluminated or unobserved; or that they change with every change in the illumination, or with every change in an observer's visual capacities; or that the same surface of the same thing has different colours for different observers. Compromise on these points, and it becomes doubtful whether the so-called 'colours' posited in your theory are rightly so-

> called. Yet it is a Moorean fact that there are colours rightly so-called. Deny it, and the most credible explanation of your denial is that you are in the grip of some philosophical (or scientific) error. (1997: 325)

By contrast, it is fair to claim that, whatever the mainstream view among scientists might be, it cannot be color objectivism. Many scientific fields are closely related with the study of color: color science, visual science, physical chemistry, physics and cognitive science.[2] The scientific outlook on color in these fields does not favor philosophers' color objectivism. Here are some instances. The leading color scientists in the 20th century, Deane Judd and Günter Wyszecki state:

> … color, itself, is not purely physical or purely psychological. It is the evaluation of radiant energy (physics) in terms that correlate with visual perception (psychology). This evaluation rests squarely on the properties of the human eye. (1975: 5)

The cognitive scientist Steven Pinker writes:

> The scientific outlook has taught us that some parts of our subjective experience are products of our biological makeup and have no objective counterpart in the world. The qualitative difference between red and green, the tastiness of fruit and foulness of carrion are design features of our common nervous system. (2008: 58)

Importantly, theoretical physicists, who seem more likely to be color objectivists due to their grasp of the best physical theories of both matter and light–matter interaction, when commenting on the nature of color, never mention that colors are properties of material object. For example, Richard Feynman claims:

> Color is not a question of the physics of the light itself. Color is a sensation, and the sensation for different colors is different in different circumstances. (2013/1963: Vol. I, Ch. 35)

[2] For an overview of these color-related sciences, see Section 8.2.

Surprisingly, in the color debate, philosophers typically assume that their views are well compatible with science, including theoretical physics. For instance, in the paper mentioned above, Lewis states:

> Let us proclaim our solidarity with forebears who, like us, wanted their philosophy to agree with ultimate physics. (1997: footnote 2)

Accordingly, if Lewis' view of color is right, then these scientists' view of color is wrong. If Lewis' proclamation of standing alongside with theoretical physics is right, then the physicists' reason to renounce color objectivism is wrong or can be overpowered by the objectivists' arguments.

There is an incongruity in color objectivists' declaring their agreement with science while being indifferent to scientists' view of color. It is unlikely that color objectivists do not know the general scientific outlook on color. But it is highly probable that they are not familiar with scientists' main reasons to renounce color objectivism, especially those from theoretical physicists who seem to have a higher probability of being color objectivists. Thus, it is unconvincing for a color objectivist to claim alignment with science while ignoring scientists' reasons for renouncing color objectivism.

Hence, to investigate the nature of color, the second challenge is that, whatever a color theory might say, it should not contradict the color-related sciences. Specifically, for color objectivism, there must be a proper way to deal with the tension between the alleged objectivity of color and the metaphysical view of color implied by the color-related sciences.

In this dissertation, the main task is to examine whether color objectivism can meet these two challenges, with the primary aim of arguing for the anti-objectivist view of colors, according to which, color objectivism is false. If the defense is successful, we can move beyond color objectivism and progress to better approaches in the study of color.

This introductory chapter sets the stage for the entire discussion. Section 1.2 gives an overview of color objectivism. Section 1.3 establishes a common ground for evaluating color objectivism. In Section 1.4, the main thesis of the dissertation, the anti-objectivist view of colors, will be formulated. Section 1.5 highlights the pivotal role of reflectance physicalism in the color debate and outlines the structure of the dissertation accordingly.

1.2 Color Objectivism: An Overview

In Subsection 1.2.1, I discuss the intuitive motivation behind color objectivism. Subsection 1.2.2 sorts six common versions of color objectivism into two groups: reflectance-grounded objectivism and color-disposition-grounded objectivism.

1.2.1 Motivation

Color experience seems to be a reliable gateway to a reality that is distinct from it. One salient aspect of the phenomenology of color experience is the stable color appearance of most ordinary physical objects. There is a robust sense that color experience can be reliably taken at face value as there are plenty of occasions where the stable color appearance of ordinary objects, like apples and walls, suggests that these objects do have the color properties that they appear to have when viewed under ordinary conditions, like in the daytime. For instance, the white appearance of a wall when viewed under daylight suggests that the wall is indeed white. In short, the stable color appearance of ordinary objects suggests that color is objective. Roughly, "objective" means that colors are perception-independent, intrinsic properties of physical objects. Call this the *simple view of color*. Many observations support this view. Taking the white appearance of a wall (viewed under daylight conditions) as an example, here are five such observations:

(i) Optical illusions: Under red light, the wall's red appearance might suggest that the wall itself is red. However, once realizing that the illumination is red light rather than daylight, one naturally concludes that the wall is actually white and that the red appearance is merely an optical illusion induced by the abnormal lighting conditions. The simple view of color is uninfluenced by optical illusions.

(ii) Surface interventions: If the wall is painted red, the wall will appear red under the same daylight conditions. This strongly suggests that colors are intrinsic properties of the wall's surface: whiteness is an intrinsic property of the unpainted wall and redness is an intrinsic property of the painted wall. The reasoning is that, under the same viewing conditions, changes in the wall's color appearances are due to changes in the microscopic properties of the objects' surface. The simple view of color can be strengthened by observing cases where interventions affect the surfaces of objects.

(iii) Color variations: The wall's white appearance might vary slightly between morning and noon light, as well as between shadowed and unshadowed regions under daylight conditions. These variations of white appearances do not undermine the simple view of color because, despite the different appearances, color experience remains a reliable guide, suggesting that the wall is white.

(iv) The counterfactualist observation: The wall's white appearance in daylight suggests not only that the wall is actually white, but also that it is white in a counterfactual sense: the wall would look white to similar perceivers under similar lighting conditions. The simple view of color can be strengthened by the counterfactualist observation.

(v) The dispositionalist observation: The wall's white appearance to a perceiver in daylight can be understood as the manifestation of the wall's disposition to *look* white to the perceiver under those conditions. The dispositionalist observation uses the notion of disposition to characterize an object's color appearance to a perceiver under specific viewing conditions. The simple view of color aligns well with the dispositionalist observation.

Mutatis mutandis for other colors and other ordinary physical objects.

Both the simple view of color and these observations are effectively captured by color objectivism. An emphasis on different observations lead to different versions of color objectivism. The next subsection will introduce the main versions.

1.2.2 Reflectance-grounded and Color-disposition-grounded Objectivism

The guiding question of the color debate is "What are colors?" For color objectivists, it is tackled by two approaches: reflectance-grounded objectivism and color-disposition-grounded objectivism. Roughly put, "reflectance-grounded objectivism" is a type of color theory which assumes that colors are reflectance-related properties, which are posited by science. By contrast, "color-disposition-grounded objectivism" is a type of color theory which assumes that colors are color-disposition-related properties that are responsible for the dispositions of physical objects to look colored to certain perceivers under certain conditions. In the following, I will classify color objectivism according to these two approaches.

In the approach of reflectance-grounded objectivism, the question "What are colors?" is specified as "Supposing that color experience is veridical under ordinary viewing conditions, like daylight, do physical objects like apples really have the colors they appear to have under these conditions?"[3] Proponents of this approach respond affirmatively to the specified question. For instance, to use red as an example, Frank Jackson claims that "[t]he prime intuition is simply that red is the property objects look to have when they look red—and if this sounds like a triviality, as surely it does, that is all to the good. It is evidence that we have found a secure starting place" (1996: 200).

This narrows down the answer to the question "What are colors?": colors are properties of physical objects, rather than properties of light or perceivers. For instance, redness is a property of objects, such as apples, rather than of the red light. This answer presupposes the simple view of color discussed in the last subsection. In particular, it meshes well with the observations from optical illusions, surface interventions and color variations.

Next, to find out the color candidate among various properties of physical objects, a causalist notion of color experience is emphasized by the proponents of this approach. They state that colors are causally efficacious properties that are responsible for the occurrences of the related color experiences. For instance, Jackson claims that "[w]e can work with the rough schema: redness is the property of objects which typically causes them to look red in the right way" (1996: 201).

Then, given that these theorists disagree about the ways in which colors are causally efficacious, there is a dispute about the nature of color. According to some theorists, reflectance properties – the intrinsic properties of objects to reflect light – are causal properties; thus, colors are intrinsic reflectance properties of objects. According to other theorists, microstructural properties – the causal/categorical bases of reflectance properties – are causal properties; thus, colors are intrinsic microstructural properties of objects. According to ye other theorists, colors are intrinsic sui generis properties of objects that are distinct from but supervene on the underlying reflectance properties. Given the causal efficacy of reflectance properties, colors are causally efficacious in a certain sense.

Accordingly, the dispute about the nature of color is reduced to the theorists' views of the relationship between colors and reflectance properties. Thus, colors are reflectance-related properties. This is why the approach is labeled "reflectance-grounded objectivism". In the literature, there are three main versions: reflectance physicalism, microstructure physicalism and color primitivism.

[3] Cf. Byrne and Hilbert (2003: 4): "The problem of color realism is posed by the following two questions. First, do objects like tomatoes, strawberries, and radishes really have the distinctive property that they appear to have? Second, what is this property?"

Reflectance physicalism: Colors are illumination-independent, mind-independent (types of) surface spectral reflectances (SSRs) of physical objects, which are intrinsic dispositional properties posited by science. This view is defended by Hilbert (1987), Matthen (1988), Tye (1995, 2000), Dretske (1995), Lewis (1997), Armstrong (1999), Byrne & Hilbert (1997, 2003, 2021) and Sharp (2023).

Microstructure physicalism: Colors are illumination-independent, mind-independent intrinsic microstructural properties of physical objects posited by physics, which are causal or categorical bases of reflectance properties, such as surface spectral reflectances. This view is defended by Smart (1975) and Jackson (1996, 1998).

Color primitivism: Colors are sui generis, illumination-independent, mind-independent intrinsic properties of physical objects, which are distinct from but supervene on the properties posited by physics, such as surface spectral reflectances. This view is defended by Campbell (1993, 2005, 2006, 2021), Stroud (2000), Watkins (2010), Gert (2008, 2017) and Allen (2011, 2015, 2016).

A property is “intrinsic” to an object iff the object has the property regardless of any factor external to the object. “Surface spectral reflectance” (SSR) means the ratio of reflected light to the incident light at each wavelength of the visible spectrum for human beings. In what follows, I reserve “SSR” as the term for reflectance properties employed by these color theories.

The three theories differ in their views on the nature of color and the relation between color and reflectance. However, they share two common theses:

(a1) Colors are properties of material objects.

(a2) Colors are essentially SSR-related properties that are intrinsic properties of material objects, where SSRs are posited by science.

Thesis (a1) is the general claim of color objectivism. Thesis (a2) is the claim of reflectance-grounded objectivism, which is a specification of (a1). Thesis (a2) is clear under scrutiny. For reflectance physicalism, (a2) is given by its definition that colors are identical with SSRs, which are intrinsic properties of physical objects. For color primitivism, (a2) is not explicitly stated by all color primitivists, but it is widely held among them.[4] For instance, the color primitivist Allen alleges that "it is commonly assumed that colours at least supervene on reflectances … This might either be because colours are identical with types of reflectance profile (as some physicalists suggest) or because colours are distinct properties that supervene on objects' reflectance profiles (as I will argue …)" (2016: 53). Given that the subvenient SSRs are intrinsic, the supervenient primitive colors are also intrinsic. Thus, colors are SSR-related intrinsic properties of objects. For microstructure physicalism, (a2) is presupposed by its definition. According to the view, colors are intrinsic microstructural properties of physical objects, which are causal or categorical bases of SSRs. This entails that colors are SSR-related intrinsic properties of objects.

Now, we turn to color-disposition-grounded objectivism. On this approach, answering "What are colors?" means to first admit the starting point that, assuming that color experience is veridical under certain conditions, for a physical object to be colored means that it is disposed to exhibit the related color look to certain perceivers under certain viewing conditions.[5] For instance, Cohen claims that "[t]his secure, if platitudinous, starting place states that things that are colored have the dispositions to look colored—i.e., to occasion certain visual experiences (to certain subjects in certain conditions)" (2009: 178).[6] Thus, colors are color-disposition-related properties. This is why the approach is labeled "color-disposition-grounded objectivism".

Note that this starting point also presupposes the simple view of color. Specifically, it aligns well with the counterfactualist and dispositionalist observations.

Next, based on the starting point that for an object to be colored means that it is disposed to exhibit the related color look, philosophers have different views on what makes a physical object so disposed, leading to different versions of color-disposition-grounded objectivism. In the literature, there are three main versions: color dispositionalism, realizer functionalism and role functionalism.

[4] Thesis (a2) is not entailed by color primitivism. The definition of primitive colors entails that colors are essentially related with properties posited by science. But many primitivists make it explicit that the required properties posited by science could well be SSRs, see Watkins 2005, Allen 2016.

[5] This formulation of the starting point of color-disposition-grounded objectivism may be disputed. For instance, McDowell holds the view that an object looks certain color to certain perceivers under the relevant viewing conditions in virtue of the object's being such as to look so, and that the property-ascription of color is *understood* to be true (1985). Here, McDowell's view is open to both a realist and an antirealist readings of colors as dispositional properties (for an antirealist reading, see Maund 2006). We leave aside the question of the proper interpretation of McDowell's view and only focus on a realist view of colors as dispositional properties.

[6] For a similar analysis, see McLaughlin 2003, 2021.

Color dispositionalism: A color property *c* is a disposition to look *c*-colored to certain perceivers in the relevant viewing conditions, where the disposition is realized by the microstructural properties of the physical objects that have the property. This view is defended by Dummett (1979, 1993), McGinn (1983), Peacocke (1984), McDowell (1985), Johnston (1992), and Levin (2000).[7]

Realizer functionalism: Pending empirical findings in science, a color property *c* is the realizer that fulfills the functional role of disposing the physical objects that have the property to look *c*-colored to certain perceivers in the relevant viewing conditions, and the color *c* must be had by everything so disposed. This view is defended by McLaughlin (2003).

Role functionalism: A color property *c* is the functional role of disposing the physical objects that have the property to look *c*-colored to certain perceivers in the relevant viewing conditions, and the color *c* is realized by microstructural properties of the objects (pending empirical evidence in science). This view is defended by Cohen (2009).

These three color theories offer different explanations of what makes a physical object disposed to look *c*-colored to certain perceivers in the relevant viewing conditions. According to color dispositionalism, a physical object is so disposed simply because the object has color *c*, which is identical with the disposition to look *c*-colored. According to realizer functionalism, a physical object is so disposed because it has color *c*, which so disposes them, where the color *c* is not the disposition to look *c*-colored but the basis common to all things so disposed, and it is a physical property posited by science. According to role functionalism, a physical object is so disposed because the object has some first-order microstructural properties (pending empirical evidence in science), which realize the second order functional role of disposing the object to look *c*-colored to certain perceivers in the relevant viewing conditions, where the functional role is identical with the color *c*.

However, despite the differences, the three theories have two common theses:

(a1) Colors are properties of material objects.

[7] In the color debate, some versions of color dispositionalism are developed in the framework of a relationalist account of dispositions. According to these views, colors are not intrinsic dispositions, see Cohen 2009. McGinn (1996) also gives a sketch of this version of color dispositionalism, according to which colors are higher-order psychophysical relations between objects and perceivers. In the current discussion, these versions of color dispositionalism are classified under role functionalism.

(a3) Colors are essentially color-disposition-related properties such that the objects having those properties are disposed to look colored to certain perceivers in the relevant viewing conditions, where the color dispositions are realized by the underlying intrinsic properties of material objects, whatever science tells us those are, such as, microstructural properties and light-disposition-related properties (including the properties to reflect light and the properties to emit light).

Thesis (a1) is the general claim of color objectivism. Thesis (a3) is the claim of color-disposition-grounded objectivism, which is a specification of (a1). Thesis (a3) is entailed by the definition of these theories. It must be noted that (a3) is an incomplete thesis, since these theorists assume that it is an empirical issue to find out the realizers of the disposition to look colored to certain perceivers in the relevant viewing conditions. Once empirical investigation decisively suggests candidates, the identified realizers can complete (a3). Put another way, whatever science may tell us about realizers, the conceptual framework of (a3) is well designed to accommodate these empirical findings. Note that these theorists might have different opinions on the most promising candidates for the realizers.[8]

As it stands, reflectance-grounded objectivism and color-disposition-grounded objectivism share (a1), which is the general claim of color objectivism. Their contrast lies between (a2) and (a3). Specifically, reflectance-grounded objectivism assumes that colors are identical with, or supervene on, or are causal or categorical bases of, the intrinsic reflectance properties, such as SSRs, which are underwritten by science. The theory does not necessarily require characterizing the objects' color appearances. In contrast, color-disposition-grounded objectivism assumes that color *c* is identical with, or the functional role of, or the physical realizer of the functional role of, the disposition to look *c*-colored to certain perceivers in the relevant viewing conditions, and that such dispositions are realized by the underlying intrinsic properties of the objects, which are underwritten by science. The theory necessarily involves characterizing *how* objects are disposed to look *c*-colored.

1.3 A Common Ground

After this overview of color objectivism, one might wonder: given so many different versions, what is the strategy to engage in the debate?

In the literature, there are two typical reactions. The first is to consider the debate as a permissive domain in which each theory is perfectly acceptable by its own standards. As

[8] The point will be discussed in Chapter 8.

Johnston (1992: 221) writes: "It seems to me that the philosophy of color is one of those genial areas of inquiry in which the main competing positions are each in their own way perfectly true."

The second is to consider the debate as a competitive arena. The hope is to find a common ground of different views, on which basis a color theory, or a kind of color theory, can then be developed. In his defense of color objectivism, Jackson (2020: 49) proposes: "Color is an incredibly controversial topic. Here is a sample of views taken seriously …. One hopes to break the impasse by finding a compelling starting point—one drawing on obvious points that are common ground—which naturally evolves into the theory of color one likes."

Both reactions assume that color objectivism is correct, the remaining issue being to determine which version.

My reaction is a third one. Given the many theories, it is reasonable to reexamine the plausibility of the existing ones, and if necessary, reject some. Specifically, I claim, in line with Jackson's proposal, that a common ground is needed to evaluate color objectivism. However, unlike Jackson's approach of arguing, based on this common ground, for some form of color objectivism, I advocate rejecting color objectivism by challenging the common ground. Accordingly, this dissertation will not argue *for* a color theory, but thoroughly examine and refute color objectivism. Section 1.4 will formulate the antithesis to color objectivism: the anti-objectivist view of colors.

What is the common ground for evaluating color objectivism? As discussed, (a1) is the general claim of color objectivism, which can be specified as either (a2) or (a3). Thus, the truth of (a1) is equivalent to the truth of the disjunction of (a2) and (a3). Importantly, a theme is addressed by both (a2) and (a3): the relation between the nature of color and the properties posited by science. Accordingly, a common ground for evaluating color objectivism arises from how its different versions incorporate the properties posited by science. Put another way, the common ground is based on clarifying how each version of color objectivism is supported by science, which is exactly to examine whether color objectivism can meet the second challenge discussed in Section 1.1. In response to this challenge, reflectance-grounded objectivism involves the SSR-related properties posited by science, which presupposes a metaphysical view of reflectance. Color-disposition-grounded objectivism involves a conceptual framework in (a3) to accommodate whatever science may tell us about the "realizers" of dispositions to look colored to certain perceivers in the relevant viewing conditions

Despite the differences, there is a common ground to how these two types of color objectivism incorporate the properties posited by science:

> Intrinsic Light Reflection Property Thesis (ILRP Thesis): The physical properties responsible for light reflection are intrinsic to objects.

For reflectance-grounded objectivism, (a2) implies the ILRP Thesis, because the SSR-related properties in (a2) involve the intrinsic properties of objects responsible for light reflection. For instance, reflectance physicalists assumes that SSRs are intrinsic properties of objects responsible for light reflection. For color-disposition-grounded objectivism, the ILRP Thesis is not explicitly stated by (a3). However, the following analysis will show that (a3) presupposes the ILRP Thesis. According to color-disposition-grounded objectivism, objects manifest their colors to perceivers in daylight, but still possess their color properties in the dark, when there is no illumination. This implies that the physical properties responsible for light reflection are intrinsic to objects. The reasoning is that objects do not lose their color properties in the dark because the objects' physical properties that determine how light interacts with them are still there. With sufficient illumination, they will reflect light and produce the related color appearances to perceivers.[9]

Note that the ILRP Thesis extends beyond color objectivism. It captures how most philosophers understand what science tells us about light reflection. David Chalmers, who is not a color objectivist, writes:[10]

> Science suggests that … [t]he properties of the object that are responsible for the reflection or radiation of the light appear to be complex physical properties, such as surface spectral reflectances, *ultimately grounded* in microphysical configurations. (2006: 20; my italic)

The ILRP Thesis also has an implication for the nature of colors: given that the properties responsible for light reflection are grounded in material properties, there must be a sense in which, whatever the nature of color might be, colors are also material-related properties.

[9] The most decisive reason for why (a3) presupposes the ILRP Thesis will be addressed in Section 8.2.
[10] For a partial introduction of Chalmers' view, see Section 9.3.

1.4 Debunking Objectivism: The Anti-objectivist View of Colors

This section presents the main thesis of the dissertation: the anti-objectivist view of colors. As discussed, the general claim of color objectivism is (a1): colors are properties of material objects. The anti-objectivist view is just a denial of (a1):

The anti-objectivist view of colors: It is not the case that colors are properties of material objects.

Given that (a2) and (a3) are two possible ways of spelling out (a1), it is expected that an argument for the anti-objectivist view of colors will have the following form:

Premise 1: Color objectivism is true if and only if (a1) is true.
Premise 2: The truth of (a1) is equivalent with the truth of the disjunction of (a2) and (a3).
Premise 3: (a2) is false.
Premise 4: (a3) is false.
Conclusion: Color objectivism is false (the anti-objectivist view of colors is true).

The argument is valid. The first two premises are conceptually true. Premise 3 and Premise 4 remain undiscussed for now. Given that the ILRP Thesis is the common ground of color objectivism, the discussions of Premise 3 and Premise 4 revolve around the same concern: whether or not this common ground is compatible with science. This will be addressed in Chapter 9, after examining all main versions of color objectivism.

Even though the anti-objectivist view of colors targets all six main versions of color objectivism, the above argument applies also to other versions and hybrid views containing color objectivism as an element, such as Shoemaker's (1991) color physicalism, Jackson's (2019) role analysis of objective colors and Brown's (2006) dual-referent approach to color theory, etc.[11]

[11] Shoemaker (1991) assumes that colors are surface properties of objects, the similarities of which are responsible for the phenomenal similarities of the related color experiences: "For surface properties of objects to be similar in color relative to a certain sort of perceptual system is presumably for it to be the case that objects with those properties standardly produce, in creatures having that sort of visual system, experiences that are similar in a certain way" (1991: 519).

According to Jackson's (2019) role analysis, "having a property that stands in such and such a set of relationships is itself a property. I think that we should identify the colours with *having* the properties that stand in the relationships, not with the properties that in fact stand in the relationships. In a familiar jargon, the suggestion is that the colours are the role properties and not the realiser properties. Instead of saying that redness, for example, is the property that stands in a certain place in N, I am suggesting that redness is the property of having the property, whatever it may be, that stands in that certain place" (2019: 827; italics in the original). In

The anti-objectivist view of colors is a negative thesis. It flatly denies that colors are properties of material objects, without specifying what colors are instead. This view has been fleshed out by many authors in the color debate.[12] Ordinarily, it is treated as the consequence of certain positive theses of anti-objectivist color theories. In order to reject color objectivism, such positive theses always include strong metaphysical assumptions about colors. There may be good reasons to endorse these assumptions. But when it comes to rejecting color objectivism, they considerably weaken the force of the arguments. For instance, the anti-objectivist view of colors is entailed by color subjectivism. Yet endorsing color subjectivism at the outset significantly weakens the force of the argument for the anti-objectivist view of colors, since color subjectivism must be validated in the first place.

In comparison, my rejection is fundamentally different. Specifically, in the dissertation, the anti-objectivist view of colors is established independently of any presupposed metaphysical assumptions about colors. As will become clear, my critique of color objectivism relies substantially on the philosophy of science, which presupposes no assumptions about colors. For this reason, most anti-objectivist color theories can be understood as different ways of spelling out the anti-objectivist view of colors. Even if these specific color theories fail, the general anti-objectivist view of colors remain intact. I will discuss some such color theories in Chapter 9.

1.5 Structure

This section is about the structure of the dissertation. Subsection 1.5.1 discusses the pivotal role of reflectance physicalism in the color debate. Subsection 1.5.2, presents the organization of the dissertation.

1.5.1 The Pivotal Role of Reflectance Physicalism

Despite intimate relations between different versions of color objectivism, these views are not on a par. In my view, reflectance physicalism is pivotal in shaping the debate of color objectivism. This has three reasons.

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the quotation, "N" stands for the color solid that represents the relations of color properties in terms of "not just difference and similarity but also degree of difference and similarity" (2019: 826).

For Brown's dual-referent approach to color theory, "one of these referents is the appearances of objects which are peculiar to colour perception, and the other is a property of external objects which marks those objects' contribution to what causes them to appear, with respect to their colour, the way they do. The former are naturally called 'colour appearances', further specification of which follows. A plausible candidate for the latter is the way objects reflect light, what is often called their spectral surface reflectance properties, or SSRs" (2006: 96).

[12] For instance, Hardin 1988, Boghossian and Velleman 1989, Maund 1995, 2006, Chalmers 2006, Pautz 2006, Chirimuuta 2015, Wright 2021 and Brown 2022.

First, reflectance physicalism has from the outset an advantage over other versions of color objectivism because it is theoretically simple to identify colors with SSRs, which shapes the debate in an important way.

Reflectance physicalism is a color theory, but it involves a metaphysical view of reflectance that is accepted by almost all color objectivists. According to this metaphysical view of reflectance, SSRs are illumination-independent, mind-independent, intrinsic surface properties of objects, which are dispositional properties posited by science. This view can be traced back to Hilbert's (1987) work, *Color and Color Perception*. According to Hilbert,

> [t]here is a well-known dispositional property of objects that corresponds to the power to transform the light striking an object. This is the surface spectral reflectance of an object. The surface spectral reflectance of an object specifies the percentage of the incident light at each wavelength that is reflected by the object. To measure the surface spectral reflectance of a given point on the surface of an object the ratio of the flux of incident light to the flux of reflected light is measured for each wavelength. Surface reflectances, thus conceived, are stable properties of objects. Leaving photosensitive surfaces aside, the reflectance of an object is independent of illumination. The intensity and wavelength of the light reaching any given point is given by the spectral power distribution of the light. (1987: 56)

> This property is an intrinsic, illumination-independent, property of the surface of an object. (1987: 65)

The view is widely followed by others.[13] Rarely have doubts been raised against it in the literature.[14] It is a sociological fact that almost all color objectivists agree that the notion of SSR is a well-established concept in science, and that SSRs are real physical properties of physical objects.[15] Furthermore, it is a sociological fact that many color objectivists assume that colors supervene on SSRs. As reported by the color primitivist Allen, "it is commonly

[13] Take Armstrong's comment on Hilbert's work as an example: "Hilbert argues that we are able with this apparatus, after processing the incoming stimuli in a sophisticated way, to pick up a quite complex property of the surface of objects. This property is called surface spectral reflectance. Here is what it is: …" (1999: 125; see also Lewis 1997).

[14] The only exception in the literature, as far as I know, is Nicholas Danne (2020). In "How to Make Reflectance a Surface Property" (2020), Danne argues that it is not the case that SSRs are illumination-independent surface properties. See footnote 46 of Chapter 3 for a simple analysis of Danne's argument.

[15] In fact, the agreement can even be extended to other color theorists who are *not* typical representatives of color objectivism, such as wave theorists of color like Webster (2002), color projectivists like Boghossian and Velleman (1989) and color eliminativists like Pautz (2006).

assumed that colours at least supervene on reflectances" (2016: 53). As a result, for color objectivists, one important issue is to make sense of the relation between colors and SSRs.[16] In particular, one central point of divergence among color objectivists is whether or not colors are identical with SSRs (reflectance physicalism) or distinct from, yet supervenient on, SSRs (color primitivism) or realized by SSRs (certain types of realizer functionalism) or being realized by the categorical bases that also realize SSRs (certain kinds of color dispositionalism or role functionalism) or themselves the categorical bases of SSRs (microstructure physicalism), etc. This divergence distinguishes different versions of color objectivism.

The simplest answer is to *identify* colors with SSRs, which results in reflectance physicalism. Hence, reflectance physicalism has a built-in advantage of. More specifically, other color objectivists are compelled to argue that their views are somehow superior to reflectance physicalism in spite of the *starting* disadvantage that they can only give a more complicated account of the relation between colors and SSRs than that of reflectance physicalism. Note that even philosophers outside of the camp of color objectivism acknowledge that reflectances are the natural candidates to identify colors with. For instance, Hardin, when arguing for color eliminativism, admits that "[s]pectral energy, reflectance and transmittance are quite obviously physically specifiable and significant … They are doubtless the characteristics of the physical world which are in some fashion picked out by perceived color; if any physical properties deserve to be identified with color, it is they" (1988: 64). In sum, reflectance physicalism shapes the debate in the sense that it has a starting advantage due to its theoretical simplicity.

Second, reflectance physicalism has an obvious advantage because it faces head-on the tension between color objectivism and the scientific outlook on color.

As mentioned in Section 1.1, one challenge for color objectivism is that it should not contradict the color-related sciences. Within color objectivism, reflectance physicalism stands out by directly facing the challenge. Reflectance physicists' notion of SSR, as a metaphysical view of reflectance, is supposed to meet the challenge. No other versions exhibit this theoretical virtue. As discussed in Section 1.2, color primitivism and microstructure physicalism are grounded in the reflectance physicists' notion of SSR. In color-disposition-grounded objectivism, there is simply no philosophy of science at all. It responds to the challenge by maintaining a general attitude to science: the conceptual framework in (a3) can accommodate whatever science may tell us about the "realizers" of dispositions. To my

[16] Of course, microstructure physicalists disagree with the statement that colors supervene on reflectances, because they hold the view that colors are categorical bases of reflectances. But they are still faced with the question of how to make sense of the relation between colors and SSRs.

knowledge, no color scientist or physicist alludes to, or even endorses, the point that these empirical findings can be accommodated by (a3). Without an in-depth study of the color-related sciences, how can one guarantee the validity of (a3)? In sum, reflectance physicalism stands out by facing head-on the tension between color objectivism and the scientific outlook on color.

Third, reflectance physicalism has a unique advantage due to its overlaps with other versions of color objectivism. The areas of overlap are the following:

(i) Many arguments for or against reflectance physicalism also apply to other versions of color objectivism. For instance, arguments against reflectance physicalism (covered from Section 3.2 to Section 3.5) applies to reflectance-grounded objectivism (to be discussed in Chapter 7).

(ii) Some arguments for or against other versions of color objectivism also apply to reflectance physicalism. For instance, Allen's argument from color constancy to color primitivism (in Chapter 7) applies equally to reflectance physicalism.

(iii) Reflectance physicalism can be incorporated into functionalism. For instance, McLaughlin's (2003) realizer functionalism includes reflectance physicalism as a sub-thesis in the case of non-fluorescent, non-phosphorescent surfaces.

No other color theory has these properties. I will discuss the point further in Section 2.3, after reflectance physicalism is presented in detail.

1.5.2 The Organization of the Dissertation

The primary aim of the dissertation is to argue for the anti-objectivist view of colors. Given the pivotal role of reflectance physicalism, the dissertation will primarily focus on examining and rejecting it. Next, it will consider how some discussions of reflectance physicalism extend to rejecting other versions of color objectivism. Finally, key points in these discussions will be highlighted to support the argument for the anti-objectivist view of color. Consequently, the dissertation has three main parts: Part I (Chapters 2–6) as the cornerstone, Part II (Chapters 7–8) as the main edifice and Part III (Chapter 9) as the culmination.

Part I examines and rejects reflectance physicalism. Chapter 2 presents reflectance physicalism, with Byrne and Hilbert's version as its representative. Chapter 3 rejects the metaphysical view of reflectances presupposed by reflectance physicalism via four arguments (from the perfect reflecting diffuser, reflectance in spectrophotometry, reflectance in electrodynamics, and the electromagnetic reflection mechanism), a criticism from reflection in quantum electrodynamics, and an analysis of reflectance physicalists' misunderstandings of reflectance in color science. Finally, Chapter 3 addresses how these results shape the ongoing discussion. Chapter 4 presents an argument targeting the combination of reflectance physicalism and the externalist representationalism it relies on, contending that the combination fails to account for simultaneous color contrast, a ubiquitous color phenomenon. Chapter 5 presents an argument against externalist representationalism (which is presupposed by reflectance physicalism), asserting that a visual scene's color phenomenology cannot guarantee the determinacy of its propositional content regarding colors, which conflicts with externalist representationalism. Chapter 6 examines the causal notion of color in reflectance physicalism. I argue that reflectance physicalism cannot include blackness as a color, because blackness does not exist in the causal process underlying color experience, as required by reflectance physicalism. Besides, I examine whether SSRs, as dispositional properties, are causally efficacious.

Part II discusses other main versions of color objectivism, classified into two groups: reflectance-grounded objectivism and color-disposition-grounded objectivism. Chapter 7 focuses on the former, examining and refuting its two main versions: microstructure physicalism and color primitivism. It also examines the role of color constancy in reflectance-grounded objectivism, using Allen's argument as a representative example. Chapter 8 shifts to color-disposition-grounded objectivism, covering its three main versions: color dispositionalism, realizer functionalism and role functionalism. I discuss how theorists of this group misunderstand the color-related sciences and then present an argument highlighting the conceptual conflict between color-disposition-grounded objectivism and electrodynamics. Chapter 8 also examines the role of color variation in color-disposition-grounded objectivism, using Cohen's argument as a representative example.

Part III rejects color objectivism. Chapter 9 establishes the main thesis of the dissertation: anti-objectivist view of colors. I first address the argument for the anti-objectivist view of color, along with a summary of the findings of the dissertation. Then, four applications of this argument are presented. Finally, I list some promising color theories that further spell out the anti-objectivist view of colors.

PART I

THE PRIME TARGET OF THE ANTI-OBJECTIVISTS VIEW: REFLECTANCE PHYSICALISM

2

Reflectance Physicalism

Chapter 1 formulated the anti-objectivist view of colors. This chapter will present its prime target: reflectance physicalism. It proceeds as follows: Section 2.1 introduces reflectance physicalism and its main features. Section 2.2 presents Byrne and Hilbert's version as its representative form. Section 2.3 revisits an underexplored point in Subsection 1.5.1, detailing how reflectance physicalism overlaps with other versions of color objectivism. Section 2.4 outlines the strategy for arguing against reflectance physicalism for the rest of Part I, covering Chapters 3–6.

2.1 Introduction: Reflectance Physicalism

According to Byrne and Hilbert, color objectivism centers on two questions: "First, do objects like tomatoes, strawberries, and radishes really have the distinctive property that they appear to have? Second, what is this property?" (2003: 4). As mentioned in Subsection 1.2.2, reflectance-grounded objectivism is motivated by these two questions.[1] Its proponents answer affirmatively to the first but differ in their opinions on the second. Specifically, reflectance physicalists' answer is that colors are illumination-independent, mind-independent (types of) surface spectral reflectances (SSRs), which are intrinsic dispositional properties posited by science. (Hilbert 1987; Matthen 1988; Tye 1995, 2000; Dretske 1995; Lewis 1997; Armstrong 1999; Byrne and Hilbert 1997, 2003, 2021; Sharp 2023).[2]

In the literature, the various arguments for reflectance physicalism are largely similar and support each other. I will take Byrne and Hilbert's (2003, 2021) argument as a representative, as it best elucidates the premises of reflectance physicalism. Regarding points not covered by this argument, Lewis' (1997) argument will serve as the main amendment. I believe the same analysis can then account for all arguments for reflectance physicalism. Before presenting Byrne and Hilbert's argument in Section 2.2, it is important to highlight some features of reflectance physicalism.

First, it is pivotal in shaping the color debate for three reasons (see Subsection 1.5.1): (i) its theoretical simplicity (ii) its facing head-on the tension between color objectivism and

[1] Color eliminativism is arguably also motivated by these questions, but it gives a negative answer to the first question.

[2] Surface spectral reflectance means the ratio of reflected light to the incident light at each wavelength of the visible spectrum for human beings. A normal human eye responds to light with wavelengths ranging roughly from 380 to 750 nanometers.

the scientific outlook on color by incorporating a metaphysical view of reflectance, and (iii) its significant overlaps with other versions of color objectivism.

Second, it applies reductionist a posteriori physicalism which employs an identity thesis. Since Kripke's (1980) work, it is widely believed by analytical philosophers that some identity claims are metaphysically necessary but epistemically a posteriori,[3] such as "Water is H_2O". Accordingly, physicalism might well be developed as a form of reductionist a posteriori physicalism, which crucially involves an identity thesis.[4] Reflectance physicalism with the identity thesis that colors are SSRs is such an application.[5] If reflectance physicalism can be established, it not only applies reductionist a posteriori physicalism but also extends Kripkean identity theses.

Third, it applies materialist metaphysics. Reflectance physicalism entails that colors are intrinsic properties of material objects. The materiality of colors is guaranteed by colors being intrinsic dispositions of material objects to reflect light. Actually, reflectance physicalism is not merely an application; it appears to be the way for a materialist to account for colors. For instance, the materialist Armstrong writes: "We want to be objective Materialists about colours … In my opinion, the most plausible theory along these lines is that advanced by David Hilbert in his short book *Color and Color Perception*, published in 1987" (1998: 125).

Fourth, it aligns well with everyday belief about colors and provides a metaphysical basis for the truth of ordinary color statements. Reflectance physicalism is compatible with the everyday belief that many material objects are colored, for instance, the belief that apples are indeed red regardless of illumination and perceiver. Similarly, reflectance physicalism can fix truth-makers of many ordinary color statements. For instance, if redness turns out to be identical with a certain type of SSR, then the truth-maker of the claim "The apple is red" is the fact that the apple has the related SSR type.

Fifth, it is supposed to account for some salient color phenomena, such as color constancy. For instance, when a perceiver has a visual experience of an apple under different illumination conditions, the apple has a stable red appearance despite the change of illumination.

[3] An identity thesis is metaphysically necessary if it is true in all possible worlds and epistemically a posteriori if known only through empirical investigation.
[4] Another form of a posteriori physicalism is realizer functionalism, which involve a functionalist analysis rather than an identity thesis.
[5] See Byrne and Hilbert 2003. "But here's the important point: rather paradoxically, a distinction may turn out not to distinguish anything! At the start of enquiry, one would want to make a distinction between salt and sodium chloride, or the butler and the murderer, even though it may turn out that salt is sodium chloride or that the butler is the murderer. It may similarly turn out with phenomenal color and (a kind of) physical color. Although care must be taken to make this distinction at the outset, perhaps phenomenal and physical color are one and the same" (2003: 6).

Reflectance physicalism accounts for the apple's red appearance by assuming that redness is the apple's SSR.

Sixth, it is part of some hybrid theories of color. For instance, Chalmers (2006) develops such a theory with redness as the example according to which, redness has two kinds: perfect redness and imperfect redness. Specifically, imperfect redness is a certain SSR. "Such a property might be called imperfect redness. In our world, imperfect redness is plausibly some sort of physical property, such as a surface spectral reflectance" (2006: 26).

Among reflectance physicalism's six features, the first (its pivotal role in the color debate) is crucial for organizing the dissertation (see Subsection 1.5.1), especially for Part I (to be discussed in Section 2.4). But it is the second feature that best motivates the ongoing discussion. It states that reflectance physicalism is a form of a posteriori physicalism. One question arises: since scientists have used the reflectance concept in color science and physics for quite a while but never claim that colors are reflectances, what motivates reflectance physicalists to identify colors with SSRs?

To answer the question, reflectance physicalists must clarify the plausibility of their identity thesis. It is a remarkable discovery that waters are H_2O. By the same token, if colors and SSRs are ultimately found to be one and the same, it would be a remarkable discovery from reflectance physicalists that, even at the beginning of the 21th century, almost no one "realizes" this. Thus, reflectance physicalism must convincingly identify the correct epistemic possibility among many to conclude that colors are SSRs.

Note that reflectance physicalists genuinely believe that their identity thesis is uninfluenced by the metaphysical implication of science for colors. Byrne and Hilbert describe one line of the reasoning:

> The main line of argument for eliminativism proceeds by claiming that science has straightforwardly shown that objects like tomatoes do not in fact have colors. The surface of a tomato has a reflectance, various microphysical properties, and is disposed to affect perceivers in certain ways. … In particular, the alleged color of the tomato does no work in causally explaining our experiences. But since a perceptible property must do this kind of causal work, this implies that we cannot perceive the color of tomato; and if we cannot perceive the color of the tomato, there is no reason to suppose that it has any color … This argument does issue a powerful challenge to those who think that tomatoes are red, but that this property is not to be identified with a reflectance, a microphysical property,

or a disposition to affect perceivers … However, it begs the question against someone who identifies redness with (say) a reflectance. (2003: 7).

One task of Part I is to show that scientists' refusal to identify colors with SSRs goes much deeper than the above reasoning: from the viewpoint of science, SSRs are not intrinsic properties of material objects at all!

2.2 Byrne and Hilbert's Reflectance Physicalism

Byrne and Hilbert's (1997, 2003, 2021) reflectance physicalism claims that colors are identical with (types of) surface spectral reflectances (SSRs). SSR is the ratio of reflected light to the incident light at each wavelength of the visible spectrum for human beings. This section discusses Byrne and Hilbert' argument.

The argument has four premises that, step by step, leads to reflectance physicalism:[6]

The causal premise: "Any plausible version of physicalism will identify the colors with physical properties implicated in the causal process that underlies the perception of color" (2003: 8).

The phenomenological premise: "Although the causal chain extends from the illuminant to the stimulus via the object, it is of course the object that looks colored (more strictly, its surface), and so the relevant physical property must be a property of objects (more strictly, surfaces)" (2003: 9).

The premise of representationalism: "[C]olor vision of human beings and many other organisms exhibits approximate color constancy, … for instance, tomatoes do not seem to change color when they are taken from a sunny vegetable patch into a kitchen illuminated with incandescent light. Assuming that our perceptions of color are often veridical, we therefore need a physical property of objects that is largely illumination-independent – a physical property that an object can retain through changes in illumination" (2003: 9).

The vision science premise: "[W]e need a property that human visual systems could plausibly recover from the responses of the three kinds of cone photoreceptors" (2003: 9).

[6] Note that the names for the premises introduced above are not used by Byrne and Hilbert. However, the added names are suitable abbreviations for the contents of the premises and it is convenient for the following discussion to use these names.

Given these premises and the background assumption that SSRs are illumination-independent, mind-independent, intrinsic dispositional properties posited by science, Byrne and Hilbert conclude: “The property that initially suggests itself is surface spectral reflectance: the proportion of incident light the object is disposed to reflect at each wavelength in the visible spectrum” (2003: 9). “Background assumption” means that Byrne and Hilbert take it as given that this metaphysical view of reflectance is well supported by science, and there is no need to argue for it. Recall what Hilbert claims, “There is a well-known dispositional property of objects that corresponds to the power to transform the light striking an object. This is the surface spectral reflectance of an object” (1987: 56) and “This property is an intrinsic, illumination-independent property, of the surface of an object” (1987: 65).

Note that these premises are not equally important. Rather, they have a “step by step” or “zoom in” structure. To frame it within a posteriori physicalism, they are systematically interlocked, all leading to the final verdict: colors are physical properties of material objects. Let us examine these premises closely.

The causal premise, as the first step, specifies a condition for colors being physical properties: colors are physical properties only if they are involved in the causal process underlying color experiences. This premise is important in suggesting where to find physical colors, namely, in the causal process underlying color experiences. Obviously, it cannot specifically identify physical colors because there are many physical properties in a causal process, such as an SSR, a disposition to look colored under certain conditions, the proximal distribution pattern of wavelengths, the neural patterns underlying the color experience, etc. To contextualize it within a posteriori physicalism, many epistemic possibilities are metaphysically possible for colors as physical properties. The causal premise accommodates too many candidates, with none particularly favored.

The phenomenological premise, as the second step, specifies a condition for colors being surface properties of objects. It is supported by the phenomenology of color experience. As the premise states, when a perceiver has a visual experience with an apple in daylight, it is the apple’ surface that looks red. Thus, the physical color must be a surface property of the apple rather than other physical properties in the same causal process, like the neural pattern underlying the color experience.

Among reflectance physicalists, this premise is open to two further readings, the intuitive reading and the introspective reading. According to Lewis' intuitive reading, it is a Moorean fact that the physical colors are properties of objects:[7]

> It won't do to say that colours do not exist; or that we are unable to detect them; or that they never are properties of material things; or that they go away when things are unilluminated or unobserved; or that they change with every change in the illumination, or with every change in an observer's visual capacities; or that the same surface of the same thing has different colours for different observers. Compromise on these points, and it becomes doubtful whether the so-called 'colours' posited in your theory are rightly so-called. Yet it is a Moorean fact that there are colours rightly so-called. (1997: 325)

By Michael Tye's introspective reading, visual experience is transparent in the sense that if one introspects what one is aware of when having color experiences, the only features of which one is aware are colors in the external world:

> … in a case of normal perception, if we introspect:
> (1) We are not aware of features of our visual experience.
> (2) We are not aware of the visual experience itself.
> (3) We cannot attend to features of the visual experience.
> (4) The only features of which we are aware and to which we can attend are external features (colors and shapes of surfaces, for example). (2014: 40)

Here, the point is not which reading is more plausible; both can strengthen the phenomenological premise by showing the intuitive appeal of identifying colors with surface properties of objects. This is enough for reflectance physicalists to furthermore locate colors on objects' surfaces. To relate it to a posteriori physicalism, this premise rules out many possibilities of what colors might conceivably be if all one had were merely the casual premise.

[7] Moorean facts are named after G. E. Moore. Roughly, Moorean facts are considered to be self-evident and intuitive, even if there are arguments or evidence to the contrary. One example of such a fact given by Moore himself is that the external world exists, which is self-evident even if there are skeptical arguments suggesting that we do not know this with certainty. However, to employ Moorean facts in argument is itself controversial, since it ultimately relies on what intuitions one endorses. In philosophical discussion, it is quite common that one philosopher's intuition is quite unintuitive to others. To some extent, it is such divergent intuitions that generate the philosophical debate. Here, we can set aside these complexities and simply admit the intuitive appeal exhibited by considering something as a Moorean fact.

Thus, one now can provisionally conclude that colors must be physical surface properties of objects.

Even though the phenomenological premise can be well supported by the two readings, Byrne and Hilbert do not adopt any of them. One main reason might be that these readings are too general and a bit far from the topic.[8] In the next premise, they have more specific concerns that are closely related with a certain color phenomenon and a metaphysical view of color perception.

The premise from representationalism, as the third step, specifies a reason for thinking that colors are illumination-independent properties of physical surfaces. The premise is based on two points.

The first pertains to the phenomenon of color constancy, according to which the objects do not seem to change their colors when perceived under different illumination conditions. For instance, ripe tomatoes seem to retain their red appearances under different illuminations.[9]

The second point is about a certain metaphysical view of color perception, which claims that color experiences have representational contents which represent the world condition before one's eyes as being a certain way. The notion "representation" is a technical term used similarly to "it seems that" or "it appears that" in some contexts. For instance, if it appears or seems to one that there is a red bulgy, tomato-like object, one's color experience represents that something is red. Accordingly, the representational content of one's experience is that a tomato-like object is red. Further, Byrne and Hilbert claim that the representational content is propositional and thus has intrinsic veridicality (or truth) conditions:

> In general, the proposition that *p* is part of the content of a subject's visual experience if and only if it visually appears to the subject that *p*. Propositions are bearers of truth and falsity: the proposition that there is a red bulgy object on the table is true just in case there is a red bulgy object on the table, and false otherwise. (2003: 5)

This view of color perception is established independently of reflectance physicalism and has many names in the philosophy of perception: intentionalism, representationalism, externalist representationalism, strong representationalism, response-independent representationalism,

[8] Reflectance physicalism "is not the product of an ideology to 'naturalize' everything that moves, or a doctrine whose main motivation is distinctively "philosophical". (Byrne and Hilbert 2021: 289).

[9] Color constancy is also emphasized by other reflectance physicalists. For instance, Tye writes that "I take color constancy … to be constancy in how things look color-wise through different lighting conditions. It is not constancy in color, period" (2012: 303).

and others.[10] In the rest of the dissertation, I use "representationalism" as the name of the view.

According to this view, color experiences represent external color-related states of affairs via their representational contents. The veridicality or non-veridicality of these contents is determined by the states of affairs. In other words, a "representational relation" exists between color experiences and color-related states of affairs, which means that representational contents intrinsically have veridicality conditions, allowing color experiences to represent the world either veridically or non-veridically.

Moreover, since color experiences also have phenomenal characters or distinctive qualitative phenomenal features, representationalists further hold that the phenomenal characters of a color experience are determined by (or is identical with) its representational content in the sense that "[t]he representational content of a subject's experience specifies the way the world appears to the subject" (Byrne and Hilbert 2003: 5). Hence, representationalism also provides a way of understanding phenomenology: phenomenology is nothing over and above representational content. Once we exhaust our understanding of the representational content of a color experience, there is nothing left to do with the phenomenology of that color experience. The point is clear in the contrast between how sense-data theory and representationalism, respectively, account for the phenomenal characters of color hallucinations.[11] Assume that one is hallucinating a red tomato-like object in a way that the *hallucinated* tomato-like object is phenomenally indistinguishable from the *perception* of a tomato. Sense-data theory accounts for this phenomenal indistinguishability by assuming that there is a common object, namely, a sense datum, shared by these two experiences. Hence, sense-data theory is somewhat phenomenologically motivated. In contrast, representationalism accounts for this indistinguishability by assuming that two experiences have the same representational content that there is something red. The representational content is associated with a veridicality condition: the content that there is something red is veridical iff there actually is something red in front of the subject. Given the worldly conditions in both cases, the hallucinatory experience is non-veridical and the ordinary color experience is veridical. Put another way, since representationalism suggests that phenomenology is nothing over and above representational content, no ontological commitment to sense data is needed, as it is mainly phenomenologically motivated.

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[10] This view is defended by Harman (1990), Tye (1994, 1995), Dretske (1995, 2000), Lycan (1996), Clark (2000) and Byrne (2001).

[11] Here, I follow Pautz' (2021) analysis. For a comprehensive discussion of different metaphysical views of perception, see Pautz 2021.

So much for representationalism. Then the question is, how do these two points, color constancy and representationalism, lead to the conclusion that colors, as physical surface properties of objects, must also be illumination-independent? Except for the direct quotation in the premise of representationalism, Byrne and Hilbert provide no further explanation. The answer might be that color constancy is best explained by assuming that color experience veridically represents the surfaces of objects as being colored in such-and-such a way. Since color constancy suggests that, despite varying illumination conditions, objects have stable color appearances, it follows that the best explanation is that the represented colors are illumination-independent. To put it within a posteriori physicalism, this premise further narrows down the range of epistemic possibilities for the color candidates. This takes it a step further: colors are not only physical surfaces properties of objects, but also illumination-independent.

The vision science premise, as the last step, claims that this property is supported by some empirical evidence showing how it *might* be recovered from the visual system. Byrne and Hilbert's only comment on this premise is: "This property is a property of objects that appear colored, it is (largely) illumination-independent, and much empirical work has been devoted to showing how it might be recovered from receptor responses" (2003: 9). Since they claim nothing substantial, there is nothing to explicate. However, in Section 3.1, I will briefly discuss that what they refer to as "empirical work" is not empirical at all, but purely conceptual models in the field of computational color constancy in color science, which are based on simplified (useful but incorrect) assumptions of light reflection.

Based on these four premises, the thesis on colors is established:

Color Thesis: colors are illumination-independent, intrinsic properties of physical objects' surfaces.

Based on Byrne and Hilbert's background view of reflectances, there is a thesis on reflectance:

SSR Thesis: SSRs are illumination-independent, intrinsic dispositional properties of physical objects.

Note that the SSR Thesis is a specification of the ILRP Thesis that the physical properties responsible for light reflection are intrinsic to objects (See Section 1.3). Given both the Color

Thesis and the SSR Thesis, Byrne and Hilbert claim that the color properties that initially suggests themselves are SSRs.

It is clear now how Byrne and Hilbert, step by step, reach the conclusion that colors are identical with SSRs.

2.3 Reflectance Physicalism and Its Objectivist Rivals

When Subsection 1.5.1 discussed the pivotal role of reflectance physicalism in the color debate, it left an underexplored point: reflectance physicalism overlaps in many details with other versions of color objectivism. Now we can revisit this point.

I will discuss the intimate relation between reflectance physicalism and its objectivist rivals – microstructure physicalism, color dispositionalism, color primitivism and realizer functionalism – successively.

The only substantial dispute between reflectance physicalism and microstructure physicalism is about the metaphysics of dispositions and causation.[12] The dispute pertains to the causal premise: what is the starting point of the causal process underlying a color experience on the side of material object? Put another way, what are the physical causes of color experiences? On reflectance physicalism, the physical causes are SSRs, because SSRs, as dispositional properties, are causally efficacious. On microstructure physicalism, the physical causes must be the categorical bases of SSRs, rather than SSRs, because SSRs, as dispositional properties, are causally inefficacious. This dispute leads to the discussion of nature of dispositions and causation.

The only substantial parallel between reflectance physicalism and color dispositionalism is their agreement about the metaphysics of dispositions and causation: Colors, as dispositional properties, are causally efficacious. Both views assume a causalist notion of dispositional properties and that colors need not be identified with their casual/categorical bases. On reflectance physicalism, colors, as SSRs, are dispositional properties causally responsible for the dispositions to reflect light in a certain way. On color dispositionalism, colors are dispositional properties causally responsible for the dispositions to look colored to certain perceivers under the relevant viewing conditions. Hence, both views agree on the metaphysics of dispositions and causation, assuming that colors, as dispositional properties, are genuine causes.

[12] Some reflectance physicalists deem microstructure physicalism more as a modification rather than an objection. As put by the reflectance physicalists, Byrne and Hilbert, "it is really more of a friendly amendment" (2003: 20, footnote 25). Some reflectance physicalists deem microstructure physicalism to be a serious objection, see Lewis 1997.

The central parallel between reflectance physicalism and color primitivism is that both share two core points of an absolutist view of colors (see Chapter 7): the intrinsicality of color and the emphasis on the color constancy phenomenon. The disagreement of the two views concerns the distinction between weak and strong physicalism. Reflectance physicalism is a type of strong physicalism since it reductively identifies colors with properties posited by science. Color primitivism is a form of weak physicalism since it does not do so. This disagreement puts primitivists on the defensive because reflectance physicalism has a built-in advantage over primitivism: Primitivists must argue that their view is somehow superior to reflectance physicalism while hampered by the *starting* disadvantage that they can only explain the relation between colors and SSRs in a more complicated way than reflectance physicalists do.[13]

Reflectance physicalism aligns well with realizer functionalism. Both are forms of a posteriori physicalism. In McLaughlin's (2003) realizer functionalism, reflectance physicalism is incorporated as a sub-thesis in the case of non-fluorescent, non-phosphorescent surfaces. As observed by many, there is no substantial conflict between the two views. For instance, Cohen claims that realizer functionalism "is, instead, a conceptually (but inessentially) dressed up form of identity theory – a theory on which colors are identical to physical types, although they may happen, contingently, to be conceived of as satisfying particular functional roles" (2009: 188).

As a result, many arguments for or against reflectance physicalism can be extended to other versions of color objectivism, and vice versa.

2.4 The Strategy of Part I

This section introduces my strategy for arguing against reflectance physicalism in the remaining of Part I, covering Chapters 3–6.

One main task of the dissertation is to examine whether color objectivism can meet the challenge from science that it must accommodate the tension between the alleged objectivity of color and the metaphysical view of color implied by science (see Section 1.1). Reflectance physicalism stands out by presupposing a metaphysical view of reflectance (the SSR Thesis) that faces head-on this challenge (see Subsection 1.5.1 and Section 2.2). Accordingly, Chapter 3 will first examine whether the SSR Thesis can meet this challenge.

Chapter 3 aims to reject reflectance physicalism by examining the SSR Thesis, which is rejected for both phenomenological (the argument from the perfect reflecting diffuser in

[13] See Allen 2016, especially Chapter 4, for such a defense. See also Watkins 2005.

Section 3.2) and scientific reasons (the arguments from reflectance in spectrophotometry, reflectance in electrodynamics, and the electromagnetic reflection mechanism in Sections 3.3–3.5), with scientific reasons as the main focus.

If these arguments work, the SSR Thesis of reflectance physicalism is false. It follows that the Color Thesis and the identity thesis that colors are SSRs cannot *both* be true. Presupposing that the SSR Thesis is false, there are three possibilities for the truth values of the Color Thesis and of the identity thesis.

The first possibility is that the Color Thesis is true and the identity thesis is false. In this context, reflectance physicalists cannot identify colors with SSRs. Instead, they might claim that colors are whatever properties suggested by the color-related science that can fit the aforementioned four premises for the Color Thesis. However, this response does not tell us the physical candidates for colors. The most crucial question of what the alleged physical colors are remains totally unanswered. If no physical colors are identified, reflectance physicalism reduces to a form of realizer functionalism that has merely a conceptual proposal to accommodate the empirical findings in science. If reflectance physicalists further look for their physical candidates for colors, in the literature, the only option compatible with the Color Thesis is microstructure physicalism. In any case, reflectance physicalism ceases to be "reflectance" physicalism.

The second possibility is that the Color Thesis is false and the identity thesis is true. This leads to two interesting results. First, colors might still SSRs (whatever science means by "SSRs"). Second, the argument for Color Thesis is unsound:

> *The Unsoundness of the Argument for the Color Thesis:* Whatever reflectance physicalists' non-reflectance-related argument for the Color Thesis is, the argument is unsound.

Namely, without examining these premises, one knows in advance that the previously presented four premises (see Section 2.2) will lead to a false conclusion. Assuming the validity of the argument, this means that at least one of the premises must be false.

The third possibility is that both the Color Thesis and the identity thesis are false. It also entails the unsoundness of the argument for the Color Thesis.

Therefore, if the SSR Thesis can be ultimately demonstrated to be false in Chapter 3, there are good reasons to endorse the unsoundness of the argument for the Color Thesis. Despite this, we will nevertheless examine the premises in the argument for the Color Thesis, aiming to find the specific mistakes in these premises. This will be the topics of Chapters 4–

6. The order of these three chapters is somewhat arbitrary, so it is possible to choose the order in which they are read.

Chapter 4 presents an argument targeting the combination of reflectance physicalism and the representationalism it involves. The argument does not rely on any independent (metaphysical, epistemological, or semantic) assumptions; it just follows from reflectance physicalism. The problems of this combination manifest themselves. All that is needed is to consider a certain ubiquitous color phenomenon, namely simultaneous color contrast.

Chapter 5 rejects the premise from representationalism by rejecting representationalism. I will argue that a visual scene's color phenomenology cannot guarantee the determinacy of its propositional content regarding colors, which conflicts with representationalism.

Chapter 6 addresses two problems of the causal premise. First, I argue that reflectance physicalism cannot account for the color membership of blackness, which is a challenge based on the well-established empirical correspondence between the absence of a causal process and the presence of a black experience. Second, I address the problems of the causal inefficacy of SSRs.

3

Light Reflection

The previous chapter presents the Color Thesis and the SSR Thesis of reflectance physicalism and mentions that the SSR Thesis is a detailed version of the ILRP Thesis that the physical properties responsible for light reflection are intrinsic to objects (See Section 1.3). This chapter will argue that the SSR Thesis is false with the following structure. Above all, I will present four arguments against the SSR Thesis: the argument from the perfect reflecting diffuser in Section 3.2, the argument from reflectance in spectrophotometry in Section 3.3, the argument from reflectance in electrodynamics in Section 3.4 and the argument from the electromagnetic reflection mechanism in Section 3.5. Then, Section 3.6 discusses light reflection in quantum electrodynamics to show not only the SSR Thesis' falsehood, but also a better scientific understanding of light reflection compared to spectrophotometry and electrodynamics. This understanding will outline the preconditions for concluding the SSR Thesis to be false based on the previous arguments. Next, Section 3.7 discusses how Byrne and Hilbert misunderstand the notion of SSR in color science. At last, I will list five consequences that will profoundly shape the ongoing discussion in Section 3.8.

3.1 The Objectivists' Metaphysics of Reflectance

Byrne and Hilbert's reflectance physicalism presupposes a metaphysical view of reflectance which is the SSR Thesis (see Section 2.2). According to this thesis, SSRs are illumination-independent, mind-independent, intrinsic surface properties of objects, which are dispositional properties posited by science. In the literature, the SSR Thesis can be traced back to Hilbert's work *Color and Color Perception* (1987) (see Subsection 1.5.1). Rarely have doubts been raised against this view.[1] It is a sociological fact that almost all color objectivists agree that the Hilbertian notion of SSR is well supported by science. Thus, it is fair to say that the SSR Thesis is *the* objectivists' metaphysics of reflectance.

Given the SSR Thesis, light reflection is explained by objects' dispositions to reflect light, popularly referred to as "light dispositions". Besides Hilbert's (1987) initial statement of the view, here are a few examples showing how widespread the notion of light disposition is in the color debate:

[1] In the literature, as far as I know, the only exception is Nicholas Danne (2020). See footnote 46 of this chapter for a simple analysis of Danne's argument.

> For when it comes to the external explanatory causes of our color experiences, psychophysics has narrowed down the options. Those causes are both non-dispositional microphysical properties, light-dispositions (reflectance, or …) …. (Johnston 1992: 224)

> Hilbert, as I understand him, thinks of the triples as themselves dispositional properties—as an object's disposition to reflect light displaying the relevant value of the triple. … But I cannot follow him in identifying the colors with these dispositions. We causalists must think of the value of the triple for a given color, red, say, as what unifies the possibly highly disjunctive basis that is responsible for the disposition to look red in normal circumstances. (Jackson 1996: 215)

> *Objection*. If colours are reflectance properties, they supervene on reflectance spectra. A reflectance spectrum is a disposition, or a bundle of dispositions, to reflect various proportions of light at various wavelengths. A disposition requires a 'causal basis'. … *Reply*. … The very same event that is essentially a having of some causal basis of a certain disposition is also accidentally a having of the disposition itself. (Lewis 1997: 331–332)

> Reflectances are also dispositions – dispositions to reflect certain proportions of the incident light. (Byrne and Hilbert 2003: footnote 13)

> A disposition to reflect or emit light predominantly of a certain wavelength
> will be a basis for the disposition to look a certain colour to P …. (McLaughlin 2003: 127)

Color objectivists rarely explicitly argue for the SSR Thesis; instead, they accept it as a given. This is evident in their approach: rather than examining the plausibility of the SSR Thesis in the *reflectance* debate, they directly proceed to explore the relation between colors and SSRs.[2]

However, what is relevant for our ongoing discussion is the question: Is the SSR Thesis true in the first place?

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[2] Recall Allen's (2016: 53) claim. "However, it is commonly assumed that colours at least supervene on reflectances … This might either be because colours are identical with types of reflectance profile (as some physicalists suggest) or because colours are distinct properties that supervene on objects' reflectance profiles (as I will argue …)". As it stands, followed by the consensus on the metaphysics of reflectance, a further point of divergence among color objectivists concerns whether colors are identical to SSRs, as reflectance physicalism posits, or whether colors are supervenient on but distinct from SSRs, as suggested by some color primitivists, or whether colors are distinct from and realized by SSRs, as suggested by some theorists of color-disposition-grounded objectivism, or whether colors are identical with categorical base of SSRs, as in microstructure physicalism, among other distinctions.

If this thesis is proven false, then reflectance physicalism is false. This chapter will demonstrate the SSR Thesis' falsehood. As a preliminary step, this section will detail the view and its motivations.

According to the SSR Thesis, SSRs are illumination-independent, mind-independent, intrinsic surface properties of objects, which are dispositional properties posited by science.[3] The thesis entails both the illumination-independence and the mind-independence of SSRs.[4] However, in the following, I mainly focus on the illumination-independence of SSRs and allude to their mind-independence only when it is relevant.[5] Here are some conceptual clarifications of the illumination-independence of SSRs:

(a) *Direction-independence.* If SSRs are independent of illumination, then SSRs are independent of the direction of the incident light and the direction of the reflected light.[6]

(b) *Frequency-independence.* If SSRs are independent of illumination, then SSRs are independent of the frequency of both the incident light and the reflected light.

(c) *Medium-independence.* If SSRs are illumination-independent properties of physical objects, then SSRs are independent of the medium in which both incident light and reflected light are transmitted.

(d) *Measurement-independence.* If SSRs are illumination-independent properties of physical objects, then SSRs are independent of the conditions under which they are measured.

These features are conceptually entailed by the SSR Thesis. If SSRs are illumination-independent, then it is conceptually true that SSRs are independent of any aspect of the incident light, the reflected light and the medium through which incident light and reflected light pass.

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[3] Specifically, the concept of SSR is grounded in the concept of reflectance factor employed in color science. See footnote 24 in Byrne and Hilbert (2003). We will discuss the relation between SSR and reflectance factor in Section 3.6.

[4] It might be assumed that the illumination-independence of SSRs entails the mind-independence of SSRs. For instance, Brown writes: "Thus, if colour is an illumination-independent feature of those things, it is independent of us" (2021: 273).

[5] Whether or not SSR are mind-independent can be dependent on one's general stance on scientific realism or an anti-realist view of science. An anti-realist view of SSR can be developed in many frameworks: instrumentalism or constructivism in philosophy of science, idealism or phenomenalism in metaphysics, among other things.

[6] Byrne and Hilbert write that "Because reflectances are not direction-dependent, this has the result that…" (2003: footnote 24).

What motivates the SSR Thesis? Even though arguments for it are rare in the literature, the underlying reasoning can be summarized as follows: To start, it seems that science tells us that, when incident light strikes an ordinary physical object, there is a stable correspondence between the measured intensity of the incident light and that of the reflected light. Then, it is intuitive to assume that, metaphysically speaking, there is a constant way in which the object reflects light, which is characterized by its reflectance properties. Moreover, if one accepts the property realism regarding dispositions, one might further refine this point by claiming that reflectance properties are just powers or dispositional properties of physical objects. For instance, "[a] reflectance spectrum is a disposition, or a bundle of dispositions, to reflect various proportions of light at various wavelengths" (Lewis 1997: 331).

Besides the above reasoning, there might be a further motivation for the SSR Thesis. In the field of computational color constancy in color science, the assumption that SSRs are illumination-independent is presupposed by a computational model that aims to describe the algorithm of an information-processing system that can estimate and recover SSRs in a given scene. The computational model is very useful to "correct color rendering in photography, in television, and in the construction of artificial visual systems for robotics" (Maloney and Wandell 1986: 1). More importantly, it also provides many insights, constraints and techniques for understanding the human visual system.[7] Of course, it is common for computational models to rely on many simplified assumptions, including the illumination-independence of SSRs. Accordingly, a color objectivist might reason that if this simplified assumption about SSRs is useful in the field of computational color constancy in color science, it is surely reasonable to generalize its underlying metaphysical view of SSRs to the color debate. For instance, Byrne and Hilbert make it explicit that their reflectance physicalism is based on the work on computational color constancy in color science.[8]

So much for the presentation of the SSR Thesis. Is this thesis true, however? The following four sections will argue that this view is false.

3.2 The Argument from the Perfect Reflecting Diffuser

This section unfolds as follows. Subsection 3.2.1 focuses on the phenomenology of reflection, which raises doubts about the SSR Thesis. Subsection 3.2.2 develops these doubts into an argument: the argument from the perfect reflecting diffuser.

[7] See Fairchild 2013: 180.

[8] Recall the visual science premise (see Section 2.2). Specifically, Byrne and Hilbert (2003: 9) cited on the works of D'Zmura 1992, Finlayson 1996, Maloney & Wandell 1986 and Funt et al. 1991.

3.2.1 The Phenomenology of Specular Reflection

Among various light reflection phenomena, this subsection specifically focuses on the phenomenology of specular reflection from opaque surfaces, which suggests initial doubts about the SSR Thesis.

To start with, the notion of the phenomenology of light reflection already comes with some baggage. It seems to involve an internal tension. On the one hand, light reflection is about how light interacts with matter at the micro-scale, which is not directly observable. Though the human eye can respond to visible light, it cannot discern an object's features at the scale of the wavelength of visible light. On the other hand, the phenomenology of light reflection primarily concerns what is directly observed by the human eye. Thus, it is only indirectly related to non-observable light–matter interactions at the micro-level, in the sense that observable markers help classify these light–matter interactions macroscopically into different types of light reflection, such as specular and diffuse reflection. In this context, "light reflection" is an observation-based concept. "Phenomenology of light reflection" is a concept based on human visual observation. For the same reason, many other notions of light behavior are observation-based concepts, too, for example, refraction, scattering, absorption.[9]

What is relevant for our discussion is specular reflection. Here are two cases.

Figure 3.1: An Apple

Figure 3.2: A Mirror

Figure 3.1 is a picture of an apple. When one observes the apple, white highlights appear on its the upper part. Intuitively, the stable red and yellow appearance suggests that red and yellow are intrinsic properties of the apple. However, the white highlights do not suggest that the related regions of the apple are intrinsically white. Instead, given the fuzzy features of the highlights and the background belief that light reflection is constantly happening on the

[9] See George Asimellis 2020: 43.

apple's surface, it is quite plausible that the white highlights are markers of specular reflection in that region.

Figure 3.2 is picture of a mirror. When one observes the mirror, the visual images in the mirror are very vivid and informative about its nearby context. Unlike the above apple case, there is no stable color appearance of the mirror itself. There is no intuition at all to take these image-forming "colors" as the colors of the mirror itself. Given the contextual features of the image-forming "colors" and the background belief about light reflection, it is quite plausible that these visual images are markers of specular reflection in all regions of the mirror.

Specular reflection on opaque surfaces is quite common and easily noticeable with a bit of attention. It varies in degrees: being salient in objects like mirrors and metal surfaces, while being less salient yet still noticeable in objects like polished wood, plastic objects, porcelain, and fruit. Moreover, polishing parts of an object' surface can dramatically increase its specular reflection. For instance, polishing the surface of a silver object that initially has a uniform white appearance can transform it into a mirror-like surface that specular-reflects light in a salient manner.

The commonality of these phenomena is that the markers of specular reflection in the regions concerned are highly contextual. These markers depend both on how an object is illuminated by incident light and on how the object is viewed in the context of seeing.

What is the relation between the phenomenology of specular reflection and the metaphysics of reflectance? The phenomenology suggests that for almost all ordinary objects, light reflection involves specular reflection to varying degrees. Thus, it is reasonable to assume that specular reflectance is a necessary component of reflectance for most ordinary objects. It is also reasonable to assume that the value of reflectance, the ratio of the measured intensity of reflected light to that of the incident light, varies according to the directions of the incident light. Hence, reflectance is direction-dependent, thus illumination-dependent. This directly conflicts with the SSR Thesis. For instance, the white highlights of the apple in Figure 3.1 suggest that its reflectance depends on the directions of the incident light.

It is a surprise, yet not quite unexpected, that color objectivists seldom mention, let alone emphasize, specular reflection on opaque surfaces and its implications for the metaphysics of reflectance. Instead, the typical attitude is to ignore it. In a footnote, Byrne and Hilbert write: "Throughout we will adopt the idealization of ignoring the specular (mirror) component of the reflectance. The component of the reflectance that is of interest to us is the body reflectance, which carries more information about the material properties of the reflecting surface" (2003: footnote 23). It seems that color objectivists consider it allowable, even reasonable, to ignore the phenomenology of specular reflection. Consequently, they omit the specular component of reflectance in their notion of SSR. Down the road, it will become clear that, in principle, it is *impossible* for any metaphysics of reflectance to leave out the specular component of reflectance.

Note that the problem associated with the phenomenology of specular reflection pertains not only to the SSR Thesis but also to the color debate, for example, to the Color Thesis. Recall that two central questions for color objectivism, as suggested by Byrne and Hilbert, are: "First, do objects like tomatoes, strawberries, and radishes really have the distinctive property that they appear to have? Second, what is this property?" (2003: 4). The phenomenology of specular reflection makes it compulsory for color objectivists to also answer the following two questions: "First, do those opaque objects like mirrors or pieces of metal have the contextual colors they appear to have? Second, what are these properties?" In the color debate, these questions are seldom discussed.[10] Omitting the phenomenon of specular reflection does not mean it does not exist. As long as it exists, the related metaphysical concerns about colors remains unavoidable.

Returning to the discussion of reflectance, the point is that the phenomenology of specular reflection clearly suggests that reflectances are illumination-dependent, contrary to the SSR Thesis.

3.2.2 The Argument from the Perfect Reflecting Diffuser

This section presents the argument from the perfect reflecting diffuser. The argument employs the method of *reductio ad absurdum*, centering on one implausible metaphysical consequence of the SSR Thesis. Here is the argument:

Premise 1: If SSRs are illumination-independent properties, then SSRs are direction-independent properties.

[10] There are some rare exceptions, such as Johnston 1992, Broacke 1992 and Matthen 2018. The most recent attempt from a *monist* color objectivist I know is Matthen 2018. It gives an account of mirror-reflected images, though Matthen remains silent about the distinction between specular reflection and diffuse reflection. Going further back, these phenomena play an important role in Broacke's (1992) wavelength theory of color. Broacke notices and emphasizes their importance: "… consider a red car on a bright day. It clearly looks red. But you will also be able to see in it the reflections of other things around, from the road and the other cars to the sky above. The surface in one sense looks a perfectly uniform colour, but almost every point on it is, in another sense, presenting a different appearance" (1992: 215). As can be seen, he comes close to characterizing the phenomena in terms of the dominance relation between specular reflection and diffuse reflection. However, he characterizes them in terms of the distinction between the uniform color and the appearance of the same surface.

Premise 2: SSRs are direction-independent properties if and only if the objects exemplifying them are the perfect reflecting diffusers (or perfect diffuse reflectors) such that, however the objects are illuminated, the reflected light is distributed uniformly in every direction.

Premise 3: It is not the case that most ordinary objects, like apples, mirrors, objects made of plastics or metals, are perfect reflecting diffusers.

Conclusion: For most ordinary objects, SSRs are not illumination-independent properties.

The argument is valid. We examine its soundness. Premise 1 is presupposed by the SSR Thesis. It is conceptually true, as demonstrated in Section 3.1.

Premise 2 is also conceptually true. Premise 2 unpacks the meaning of direction-independence with a biconditional statement. For a perfect reflecting diffuser, whatever the incident light is in a given context, both globally and locally, it must reflect light in a perfectly diffuse manner such that there is a uniform distribution of the reflected light with the same intensity everywhere. Figure 3.3 is a graphical representation of a perfect reflecting diffuser. Otherwise, if diffuse reflection is imperfect regarding the direction of the reflected light, there might be, for instance, some noticeable specular reflection in some areas. As discussed in the last subsection, this suggests that reflectances of these areas depend on the direction of the incident light, which conflicts with the definition of direction-independence. Hence, Premise 2 is conceptually true.

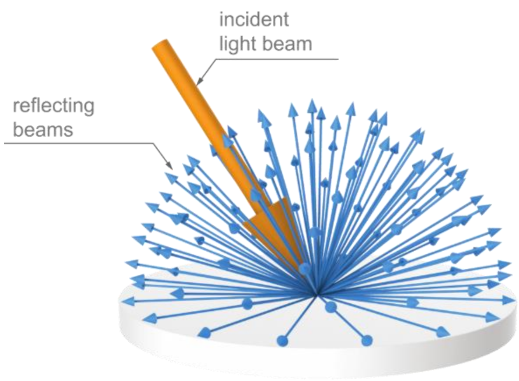

Figure 3.3: A Perfect Reflecting Diffuser

Premise 3 is based on empirical observation in ordinary contexts.[11] Subsection 3.2.1 shows that it is phenomenologically obvious that most ordinary objects like apples, mirrors, objects

[11] Here, one can appeal to the notion of nomological or metaphysical necessity to turn Premise 3 into a modal claim such as "As a matter of nomological (or metaphysical) necessity, it is not the case that objects are the perfect reflecting diffuser." But for the sake of our purpose, empirical observation in ordinary contexts is adequate.

made of plastics or metals, among others, do not reflect light in a perfectly diffuse manner. It follows that these objects are not perfect reflecting diffusers. The point can be strengthened by considering that some polishing or a simple scratch can add some specular reflection on an object, which can easily make the specular reflection imperfect. Thus, it is fair to claim that most ordinary objects are imperfect reflecting diffusers (or imperfect diffuse reflectors) such that their reflectances are highly dependent on the direction of the incident light. Figure 3.4 is a graphical representation of an imperfect reflecting diffuser.

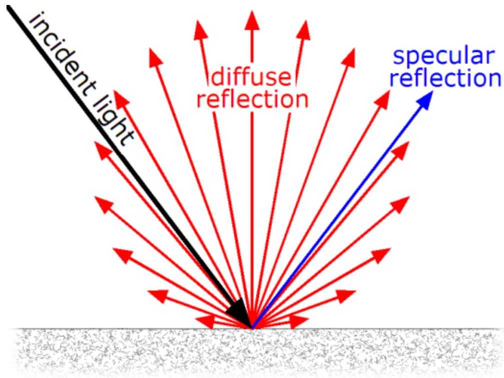

Figure 3.4: An Imperfect Reflecting Diffuser

Note that an ordinary object being an imperfect reflecting diffuser does not mean that there must be noticeable specular reflections from the object. Put another way, even regions of an object where specular reflection is dominated by diffuse reflection, and no such markers are noticeable, need not exhibit perfect diffuse reflection. Specular reflection cannot be excluded by the definition of reflectance, even if it is not noticeable. If specular reflection is included, diffuse reflection is not perfect. This analysis suggests that it is metaphysically implausible that most ordinary objects are perfect reflecting diffusers. Thus, Premise 3 is validated.

Therefore, we can conclude that for most ordinary objects, SSRs are not illumination-independent properties. Accordingly, the SSR Thesis is false.

3.3 The Argument from Reflectance in Spectrophotometry

This section presents the argument from spectrophotometry. While the argument from the perfect reflecting diffuser in the last section reveals a metaphysical implausibility entailed by the SSR Thesis, it does not explore why the SSR Thesis entails this implausibility. By contrast, the argument from spectrophotometry will shed more light on why the SSR Thesis is false by focusing on the proper metaphysical interpretation of the concept of reflectance employed in spectrophotometry in color science. Here is the argument:

Premise 1: If SSRs are illumination-independent properties, then SSRs are direction-independent properties.

Premise 2: SSRs are direction-independent only if the proper metaphysical interpretation of the concept of reflectance in spectrophotometry suggests their direction-independence.

Premise 3: The proper metaphysical interpretation of the concept of reflectance in spectrophotometry does not suggest so.

Conclusion: SSRs are not illumination-independent properties.

The argument is valid. We examine its soundness. Premise 1 is conceptually true, as demonstrated in Section 3.1.

Premise 2 claims that the direction-independence of SSRs is constrained by the concept of reflectance in spectrophotometry. The SSR Thesis is based on spectrophotometry in color science. After all, the concept of reflectance was not invented by the color objectivists. Premise 2 just summarizes what they do when they introduce the SSR Thesis. Byrne and Hilbert, for instance, make this explicit: "Because reflectances are not direction-dependent, this has the result that …. For precise definitions of 'reflectance' and 'reflectance factor'," see Judd and Wyszecki (1975, p. 463)" (2003, footnote 24), where the cited work is about reflectance in spectrophotometry. Thus, Premise 2 is validated.

Premise 3 is the crux of the argument. What is the proper metaphysical interpretation of the reflectance concept in spectrophotometry?

We start with the definition of reflectance in spectrophotometry. According to its latest definition in the international standard CIE S 017:2020 ILV: International Lighting Vocabulary, 2nd edition, reflectance ρ is the "quotient of reflected radiant flux, Φr, and incident radiant flux, Φm. … Reflectance is also defined spectrally in terms of wavelength, in which case, 'spectral' is added before the quantity name. … Reflectance, ρ, is the sum of regular reflectance, ρ_r, and diffuse reflectance, ρ_d: $\rho = \rho_r + \rho_d$".[12,13] Specifically, the definition

[12] CIE stands for International Commission on Illumination. For the entry on the definition of reflectance, see https://cie.co.at/eilvterm/17-24-064.

[13] Byrne and Hilbert's (2003) notion of reflectance relies on Judd and Wyszecki's (1975) definition of reflectance in spectrophotometry. Judd and Wyszecki did not adopt the definition that reflectance is the sum of regular and diffuse reflectance, but they made it explicit that the definition of reflectance must factor in both. Specifically, they treat reflectance as a limiting case of the reflectance factor (more on this in Section 3.7). But Wyszecki and Stiles (1982) made the point explicit that reflectance is the sum of regular and diffuse reflectance, which is the same as the current definition of reflectance used in spectrophotometry. I will discuss Byrne and Hilbert's misunderstanding of Judd and Wyszecki's (1975) notion of reflectance in Section 3.7.

of regular (or specular) reflectance is the "quotient of the regularly reflected part of the (whole) reflected flux and the incident flux".[14]

According to these quotations, the definition of reflectance necessarily involves the thesis that reflectance is the sum of specular (or regular) reflectance and diffuse reflectance, where specular reflectance is defined as the ratio of the specularly reflected part of the whole reflected flux to the incident flux. "The specularly reflected part of the whole reflected flux" entails that the directions of the specularly reflected flux must be factored into the definition of reflectance.

What is the proper metaphysical interpretation of this definition of reflectance?

In the following, I will assume realism about reflectances.[15] Since reflectance is the sum of specular and diffuse reflectance, and specular reflectance factors in the directions of the specularly reflected flux, the proper metaphysical interpretation of this definition must entail that reflectance is direction-dependent. This directly conflicts with the direction-independence of SSRs implied by the SSR Thesis.

Thus, the argument concludes: SSRs are not illumination-independent properties (the SSR Thesis is false).

Note that this argument also tells us that the reason for the metaphysical implausibility entailed by the SSR Thesis, suggested by the argument from the perfect reflecting diffuser, is that the SSR Thesis fails to factor in specular reflectance.

3.4 The Argument from Reflectance in Electrodynamics

This section highlights the tension between the SSR Thesis and the reflectance concept in electrodynamics by discussing the *argument from reflectance in electrodynamics*. Compared with the previous two arguments in Sections 3.2–3.3, this argument delves deeper into the underlying reasons for the falsehood of the SSR Thesis. More specifically, this argument relies on the metaphysical interpretation of reflectance (or the reflection coefficient) in electrodynamics. Here is the argument:

[14] See the entry on specular reflectance, https://cie.co.at/eilvterm/17-24-066

[15] Certainly, there is some room for an anti-realist view of reflectance. An anti-realist view of reflectance can be that reflectance is no more than a concept used in spectrophotometry such that no ontological commitment of the existence of reflectance properties is required. For instance, one line of reasoning is as follows: given that, strictly speaking, Judd and Wyszecki's (1975) definition of reflectance is different from Wyszecki and Stiles's (1982) the definition of reflectance, anti-realist can claim that the change of the definition of reflectance is no more than a matter of conceptual refinement for practical needs arisen from the measurement of light. The ontological commitment of the existence of reflectance is pleonastic.

Premise 1: If SSRs are illumination-independent properties, then SSRs are direction-independent properties.

Premise 2: SSRs are direction-independent only if the proper metaphysical interpretation of the concept of reflectance in electrodynamics suggests their direction-independence.

Premise 3: The proper metaphysical interpretation of the concept of reflectance in electrodynamics does not suggest so.

Conclusion: SSRs are not illumination-independent properties.

The argument is valid. We examine its soundness. Premise 1 is assumed by the SSR Thesis. It is conceptually true, as demonstrated in Section 3.1.

Premise 2 claims that the direction-independence of SSRs is constrained by the reflectance concept in electrodynamics. Electrodynamics, based on Maxwell's equations, provides a fundamental framework for understanding light reflection. It successfully describes light–matter interaction when quantum phenomena are not considered. Thus, any metaphysical view of reflectance must be constrained by the reflectance concept in electrodynamics, including both the SSR Thesis and the reflectance concept in spectrophotometry. It is trivially true that the direction-independence of SSRs in the SSR Thesis is constrained by electrodynamics. Hence, Premise 2 is validated.

But what is the relation between the reflectance concept in spectrophotometry and that in electrodynamics? Why should the metaphysics of the former be constrained by that of the latter?

Electrodynamics offers a fundamental framework for the measurement of reflectance in spectrophotometry.[16] In spectrophotometry (see Section 3.3), according to the CIE S 017:2020 standard, "Reflectance is also defined spectrally in terms of wavelength." Electrodynamics is just the domain where light is understood as electromagnetic radiation, which means, roughly, as waves (with a spectrum of wavelengths) that spread in space in the form of electric and magnetic fields. Hence, the metaphysics of the reflectance concept in spectrophotometry is constrained by that of electrodynamics.

Premise 3 is critical to the argument. What is the proper metaphysical interpretation of the reflectance concept in electrodynamics?

[16] See Judd and Wyszecki 1975 and Wyszecki and Stiles 1982. Color scientists fully respect electrodynamics. But the point is rarely discussed by philosophers in the color debate.

I assume realism about reflectances[17] and exclude quantum phenomena in the following. Note that color objectivists' SSR Thesis primarily applies to ordinary opaque objects, while reflectance in electrodynamics applies to *all* cases of light reflection. In electrodynamics, a quantitative analysis of reflectance for transparent objects is easier due to their simple material constitution,[18] while it is challenging for opaque objects due to their complex material constitution; nonetheless, a *qualitative* analysis of reflectance works for both transparent and opaque objects.[19] In the following, my strategy is to first describe the quantitative analysis of reflectance for transparent objects and then generalize the qualitative analysis underlying this quantitative analysis to opaque objects.

This strategy is robust against color objectivists' objections, because it aligns with their approach, which also extends an analysis of reflectance to transparent objects. Byrne and Hilbert's notion of productance is just such a generalization: "the *productance* of a surface is its disposition to produce (i.e., reflect or emit or transmit) a specific proportion of incident light" (2003: 11). Specifically, they assume that "transparent volumes like glasses of beer can be thought of as composed of layers of filters" (2003: 12), and "[i]n the case of the filter, … take the reflectance to be measured by the usual ratio, but with the entire filter (i.e., its front and back) uniformly illuminated" (2003: 12).

Here is the qualitative analysis of reflectance for transparent objects with an isotropic lattice structure that absorbs almost no light (like glass):[20]

> In electrodynamics, light is understood as a transverse wave that consists of oscillating electric fields, E, and magnetic fields, B. The oscillations are perpendicular to the direction of light propagation. The following analysis assumes that the light is unpolarized, like sunlight, and the transparent material is dielectric, like glass.[21]
>
> Assume that the incident light through medium *A* (refractive index = n_1), e.g., air, strikes the interface between medium *A* and medium *B* (refractive index = n_2), e.g., a pane of

[17] An anti-realist view of reflectances can result from instrumentalism or constructivism in the philosophy of science.
[18] For instance, a transparent object, due to its isotropic lattice structure, has a single dielectric constant, which simplifies many assumptions about the material constitution in the theoretical model of a quantitative analysis of reflectance.
[19] In electrodynamics, the most frequently discussed case is light reflection at the interface of air and another transparent (or translucent) object, such as glass. I have not found any discussion of opaque cases.
[20] The qualitative analysis of reflectance is roughly the same in different textbooks in physics. Here, I primarily follow Feynman 2013 and Asimellis 2020. See also Hecht 2017 and Griffiths 2024.
[21] Light being unpolarized means that the electric field vectors of light are in all directions perpendicular to the direction of propagation, like in sunlight.

glass. The angle of incidence is ϑ_i. The reflectance R is defined as the ratio of the reflected flux to the incident flux, $R = I_r/I_i$. The amplitude reflection coefficient ρ is defined as the ratio of the reflected amplitude magnitude E_r to the incident amplitude magnitude E_i, $\rho = E_r/E_i$. Here, ρ and R stand in the following relation: $R = I_r/I_i = \rho^2 = (E_r/E_i)^2$.

For unpolarized light, the polarization of light can be analyzed as two polarization eigenstates: parallel eigenstate and perpendicular eigenstate. The *parallel* eigenstate is the state where the electric field vector is parallel to the plane of incidence, while the magnetic field vector is perpendicular to the plane of incidence. The *perpendicular* eigenstate is the state where the electric field vector is perpendicular to the plane of incidence, and the magnetic field vector is parallel to the plane of incidence.[22]

There are many ways to establish the equations of light reflection.[23] We neglect the details of these equations and focus on the result. Finally, there is a quantitative expression of the reflection coefficient ρ. For the parallel eigenstate, a relative refractive index ratio $n_{21} = n_2/n_1$ and an angle of incidence ϑ_i, the coefficient ρ_p is

$$\rho_p(\vartheta_i, n_{21}) = \left(\frac{E_r}{E_i}\right)_p = \frac{-n_{21}^2\cos\vartheta_i + \sqrt{n_{21}^2 - \sin^2\vartheta_i}}{n_{21}^2\cos\vartheta_i + \sqrt{n_{21}^2 - \sin^2\vartheta_i}}$$

For the perpendicular eigenstate, the coefficient ρ_s is

$$\rho_s(\vartheta_i, n_{21}) = \left(\frac{E_r}{E_i}\right)_s = \frac{\cos\vartheta_i - \sqrt{n_{21}^2 - \sin^2\vartheta_i}}{\cos\vartheta_i + \sqrt{n_{21}^2 - \sin^2\vartheta_i}}$$

These two formulas clearly show that ρ_p and ρ_s depend on the angle of incidence, ϑ_i, and the relative refractive index ratio, n_2/n_1, where the refractive indexes n_1 and n_2 depend on both the frequency of the incident light and the material constitution of the object.

What is the proper metaphysical interpretation of the reflectance R?

It is clear that, metaphysically, ρ_p and ρ_s depend on the complex of the angle of incidence and the refractive index of the two media in the context. Given that the relation between the

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[22] To my knowledge, there are two ways to establish the equations of light reflection. The first way is by using Maxwell's equations, see Feynman 2013: Vol. II, Ch. 33. The second way is to use the combination of the law of reflection, the law of energy conservation and the zero net effect of the electric field of the source and the induced electric field at the boundary of two mediums. See Feynman 2013: Vol. I, Ch. 33-6, and Asimellis 2020: 88.

[23] See especially Hecht 2017.

reflectance R and the coefficient ρ is $R = \rho^2$, it follows that, metaphysically, the reflectance R depends on the angle of the incident light and the refractive indexes of the two media in the context, where the refractive indexes of the two media further depend on the frequency of the incident light and the material constitution of the objects. Note that this analysis presupposes that the light is unpolarized. If the polarization states of the light are considered, reflectance would then metaphysically depend on the particular polarization states of the light, the particular angle of the incident light and the particular refractive index of the two media in the given context.

The above analysis shows that reflectance depends on the context. Thus, we can conclude that reflectances are *contextual* properties of the interaction between light and media.[24] The incidence, the refractive index and the polarization state of light are parts of the context and thus vary with the context. Hence, it cannot be the case that reflectances are intrinsic, and thus context-independent, properties of a transparent object. This entails that reflectances are not context-independent common properties of different transparent objects but rather contextual properties specific to particular situations. Concerning Premise 3, the above analysis rejects the direction-independence of reflectances for transparent objects. Hence, the proper metaphysical interpretation of reflectance for transparent objects in electrodynamics does not suggest the direction-independence of SSRs. Therefore, Premise 3 is validated.

Now I will generalize the qualitative analysis of reflectance from the case of transparent objects to that of ordinary opaque objects.[25]

The preliminary characterization of how light interacts with ordinary opaque objects is as follows: When incident light in medium n_1 strikes the surface of an ordinary object, one portion of the light is directly reflected back into the medium n_1 in a mixture of both specular and diffuse reflection. The other portion penetrates the object, after complex absorptions, scatterings and internal reflections, some of which scatter back into n_1 in a more or less diffuse manner.[26, 27] This characterization is preliminary because it neglects the electromagnetic wave nature of light, as suggested by electrodynamics. Nevertheless, for the purpose of falsifying the SSR Thesis, this characterization is sufficient. However, another electrodynamics-based

[24] Here, a material object is also a medium.

[25] Textbooks in physics seldom mention directly how light interacts qualitatively with ordinary opaque objects, but they provide the basic framework for a qualitative analysis. Hecht 2017: 142–146, is a helpful summary. But the topic is certainly covered by color scientists. The following analysis relies on my synthesis of Judd and Wyszecki 1975, Wyszecki and Stiles 1982, Hecht 2017, Asimellis 2020 and Feynman 2013: Vols. I and II.

[26] See Judd and Wyszecki 1975: 92–93, 413–420.

[27] Internal reflection is the phenomenon where light transmitted inside a medium strikes the interface to a medium with a lower refractive index and is reflected back into the original medium on the condition that the angle of incidence is greater than the critical angle of the two media.

argument (see Section 3.5) will characterize the reflection mechanism by the electromagnetic wave nature of light.

In this preliminary characterization, reflectance can be well understood as the sum of two components.[28] The first component is the ratio of the directly reflected light (from the interface between the medium n_1 and the object) to the related incident light. Call this the *directly reflected* component of reflectance. The second component is the ratio of the scatteringly reflected light (which, after penetrating the object, undergoes absorption, scattering and internal reflection and is then diffusely scattered back into the medium n_1) to the related incident light. Call this the *scatteringly reflected* component of reflectance.[29]

The analysis of the directly reflected component of reflectance for ordinary opaque objects is the same as the quantitative analysis of reflectance for transparent objects. The reason is that the aforementioned formulas apply to the both cases. According to electrodynamics, the formulas are applicable when there is a sudden change of refractive index:

> The formulas we will derive are correct only if the change of index is sudden—within a distance very small compared with one wavelength. For light, the wavelength is about 5000 Å, so by a "smooth" surface we mean one in which the conditions change in going a distance of only a few atoms (or a few angstroms). (Feynman 2013: Vol. II, Ch. 33-1)

Supposing that the mentioned medium n_1 is air (the refractive index of which is approximately 1.0003), there must be a layer at the interface between the air and the (transparent or opaque) object where there is a sudden change of the refractive index. Thus, the stated formulas apply to both the reflectance for transparent objects and the directly reflected component of reflectance for opaque objects.

For transparent objects, the proportion of scatteringly reflected light in the overall reflected light is much lower and negligible. The value of reflectance (the ratio of the reflected flux to the incident flux) simplifies to the ratio of the directly reflected flux to the incident flux. For ordinary opaque objects, there is no such simplification; the value of reflectance must involve both the directly reflected component and the scatteringly reflected component.

[28] This notion of reflectance is in the same spirit as the definition of reflectance in the international standard CIE S 017:2020 ILV, according to which "Reflectance, ρ, is the sum of regular reflectance, ρ_r, and diffuse reflectance, ρ_d: $\rho = \rho_r + \rho_d$".

[29] As a comparison, see Judd and Wyszecki's definition of the reflectance factor (1975: 93) as a quantitative analysis of reflectance, which will be discussed in Section 3.7. My analysis adds some modifications to Judd and Wyszecki's definition of reflectance factor in order to avoid using the concept of the perfect reflecting diffuser. As a consequence, we only have a qualitative rather than a quantitative analysis.

Namely, the value of reflectance must factor in the directly reflected component. Consequently, any metaphysical assumption about the directly reflected component of reflectance applies also to that of the overall reflectance.

Our previous discussion has demonstrated that, for transparent objects, reflectances are *contextual* properties of the interaction between light and media, including both air and material media. Given that the analysis of reflectance for transparent objects is the same as that of the directly reflected component of reflectance for opaque objects, it follows that, for opaque objects, the directly reflected component of reflectance is also a contextual property. Hence, for opaque objects, (the overall) reflectances are *contextual* properties.

Back to Premise 3: For the case of ordinary opaque objects, reflectance depends on the angle of the incident light in the given context, because the directly reflected component of the reflectance varies with this angle. It follows that the proper metaphysical interpretation of the reflectance concept in electrodynamics does not suggest the direction-independence of SSRs. Thus, Premise 3 is validated.

Therefore, the argument concludes: SSRs are not illumination-independent properties.

Note that this argument targets the illumination-independence of SSRs. With adjustments, it can also target the *medium*-independence of SSRs (see Section 3.1). As demonstrated, reflectances are contextual properties of the interaction between light and media, including both air and material media. It follows that SSRs are not medium-independent properties.

Another way to reject the medium-independence of SSRs is to consider internal reflection. As mentioned in footnote 27 of this chapter, when transmitted in a medium and striking another medium with a lower refractive index, light is reflected back into the original medium on the condition that the angle of incidence is greater than the critical angle of the two media. Specifically, the scatteringly reflected component of the reflectance varies with these two angles. Since the critical angle is a property of the combination of these two media, SSRs are not medium-independent properties.

3.5 The Argument from the Electromagnetic Reflection Mechanism

This section demonstrates the conflict between the SSR Thesis and the mechanism of light reflection in electrodynamics through an argument called *the argument from the electromagnetic reflection mechanism*. Compared with the previous three arguments, this argument probes deeper into the reasons for the falsehood of the SSR Thesis. Specifically, it provides a full picture of the electromagnetic (EM) reflection mechanism for ordinary opaque objects from the viewpoint of electrodynamics. Here it is:

Premise 1: The SSR Thesis implies that the primary physical properties responsible for light reflection are intrinsic dispositional properties of objects.

Premise 2: Light reflection is an EM reflection.

Premise 3: The EM reflection mechanism in electrodynamics implies that the primary physical properties responsible for EM reflection are not intrinsic to objects.

Conclusion: If electrodynamics is true, then the SSR Thesis is false.

The argument is valid. We examine its soundness. Premise 1 is conceptually given by the SSR Thesis.[30]

Premise 2 is conceptually true. According to electrodynamics, light is an EM wave. Thus, light reflection is an EM reflection.

Premise 3 is a crucial premise. To start with, what is the EM reflection mechanism?

According to electrodynamics, light is a transverse EM wave. Such waves consist of the oscillation of an electric field and a magnetic field, which are perpendicular to each other and to the direction of propagation. In physics, an "oscillating field" is a field that varies sinusoidally with time. Light reflection is understood as the process in which incoming EM waves interact with the boundary area between two media, such as air and an apple. This interaction results in changes to the characteristics of the outgoing EM waves, such as changes in direction, intensity and polarization, among others, compared to those of the incoming EM waves. Importantly, in this process, the outgoing EM waves can further be understood as the *re-radiated* EM energy emitted by the temporarily induced radiators instantiated in the process. In electrodynamics, the theory of EM radiation is devoted to the study of the generation and propagation of EM waves from the perspective of how they are generated by moving charges and how they propagate and interact with the charges carried by matter. Specifically, EM waves can be generated through different mechanisms, including but not limited to:

(i) the rapid oscillation of electrons, like in antennas,
(ii) electron transition through different energy levels, like in LEDs,
(iii) temporary electric dipoles, where light interacts with a dielectric object, such as an apple illuminated by daylight.

[30] Recall Hilbert's statements: "There is a well-known dispositional property of objects that corresponds to the power to transform the light striking an object. This is the surface spectral reflectance of an object" (1987: 56), and "This property is an intrinsic, illumination-independent, property of the surface of an object" (1987: 65).

These phenomena are called “radiation”. What is relevant to the ongoing discussion is (iii), as it pertains to the EM reflection mechanism in for ordinary objects like apples, leaves and walls, which are central to the color debate. For example, consider an apple with a stable red appearance in daylight. The EM reflection mechanism is as follows:

- *Surface reflection:* When incident light strikes the apple, a portion is directly reflected back into the air at the interface between the apple and the air, involving specular and diffuse reflection. The reflection coefficient ρ of this surface reflection was discussed in the last section. The mechanism underlying this is called *the mechanism of oscillating dipoles*, which is also identical to one of the two mechanisms for the further interaction between the penetrating light and the apple (see below).

- *Secondary reflection*: For the portion of light that penetrates the apple, the following two mechanisms happen simultaneously: resonant absorption and dipole oscillation.

  The mechanism of resonant absorption:
  Due to the wave nature of light, resonant absorption of light happens when the frequency of the incoming light matches the inherent frequency of an oscillating system (determined by the molecule–electron or atom–electron structure of the material): light at that frequency is absorbed to significant degree. The pigment molecules in the apple are oscillating systems with inherent frequencies within the visible spectrum. Thus, for the portion of light that penetrates the apple, only the light with the matching frequency is absorbed significantly.

  The mechanism of oscillating dipoles:
  For the portion of light that penetrates the apple, its oscillating electric field induces rapid oscillations of the electrons within the apple’s material. These oscillations create oscillating dipoles that radiate their energy scatteringly at the frequency of the incident light.[31]

[31] See Asimellis’ characterization: “These shifts follow the fluctuations of the electric field, so the electron distribution is brought into oscillation. This classical energy exchange corresponds to non-resonant absorption. The absorption creates an oscillating dipole, which is an elementary emission unit. The oscillating dipole re-emits the absorbed energy in all directions at the oscillating frequency of the original wave” (2020: 84).

In this process, the energy exchange between the incident light and the electrons involves non-resonant absorption, where the absorbed energy is transformed wholly into the energy of the oscillating dipoles. In the theory of EM radiation, "oscillating temporary dipole", "oscillating dipole", "temporary dipole", "temporary electric dipole" and "temporary dipole moment" are used interchangeably. They refer to the oscillations of the temporary imbalance in the distribution of positive and negative electrical charges that are induced by the incident light in the process of its interaction with the dielectric material. Importantly, first, "temporary imbalance in the charge distribution" means that the existence of the imbalance of the charge distribution is temporary. Its temporary existence is completely dependent on the incident light. Specifically, it is the electric field of the incoming incident light that induces such a temporary imbalance. When the incident light stops, the imbalance in the charge distribution ceases to exist.[32] Second, "oscillating" means that the temporary imbalance in the charge distribution varies sinusoidally with time. Third, according to the theory of EM radiation, an oscillating dipole is an EM radiator that radiates light scatteringly such that the frequency of the scattered light is equal to the frequency of the oscillating dipole, which is also equal to the frequencies of both the oscillating electrons and the related incident light that induces the electron oscillation. Typically, an oscillating dipole can be modeled as two charges, q and $-q$, separated by a small distance such that there is an oscillating dipole moment.

- *Overall reflection:* In the case of the apple, the overall reflected light consists of the light from surface reflection and that from secondary reflection, both of which are due to the mechanism of oscillating dipoles. Thus, the overall reflected light is *generated* by oscillating dipoles. Specifically, the light from secondary reflection is the main portion of the overall reflected light.[33]

- *A quantitative model*. To provide a quantitative analysis of the relation between reflected light and an oscillating temporary dipole, in EM radiation, the equation of

[32] Of course I assume that there are no additional external electric fields acting on the object.
[33] If the light from secondary reflection were not the main portion, the apple would not have a stable red appearance.

the far-away electric field produced by an oscillating dipole is:[34, 35]

$$\mathbf{E} = -\frac{\mu_0 p_0 \omega^2}{4\pi}\left(\frac{\sin\theta}{r}\right)\cos[\omega(t - r/c)]\,\hat{\boldsymbol{\theta}}$$

Here, t is time, p_0 is the amplitude of the dipole moment, ϵ_0 is the permittivity of space, c is the speed of light, ω is the angular frequency of the oscillating dipole, r is the distance from the oscillating dipole to the observation point, **E** is the far-away electric field at the observation point, θ is the angle between the dipole axis and the line from the dipole to the observation point, $\hat{\theta}$ is the unit vector in the direction perpendicular to both the dipole axis ($\hat{z}$) and the line from the dipole to the observation point and $p_0 \cos \omega t \hat{z}$ is an oscillating dipole with frequency ω and amplitude p_0 along the dipole axis $\hat{z}$.

Even though this equation is modeled on a single oscillating dipole, it provides a quantitative base to capture some essential features of light reflection for most ordinary dielectric objects where there is a great number of oscillating dipoles. Many complexities make it hard to quantitatively model the case of an ordinary dielectric object.[36] But for a *qualitative* analysis, there is no great difference between a single oscillating dipole and multiple oscillating dipoles. It is clear that, for an oscillating dipole, the value of **E** at the observation point is determined by the features of the *earlier* oscillating dipole, $p_0 \cos[\omega(t - r/c)]\hat{z}$, with a time delay of r/c, not by the features of the oscillating dipole at that very moment. Similarly, it is reasonable to assume that, for most ordinary dielectric objects where there are multiple oscillating dipoles, the reflected light at the observation point is determined by the features of the *earlier* oscillating dipoles with a time delay of r/c.

Given this the EM reflection mechanism for most ordinary dielectric objects, let's get back to the discussion of Premise 3. First, what does this mechanism imply metaphysically? Second,

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[34] In physics, a "far-away" electric field means that the field is observed at a considerable distance from its source charges.

[35] For the deduction of this equation, see Griffiths 2024: 476. But to give a qualitative analysis, the equation of the far-away electric field produced by a moving charge is enough, and the deduction of this is much simpler than that of the far-away electric field produced by an oscillating dipole, see Feynman 2013: Vol. I, Ch. 28-2.

[36] I believe that the main difficulty is that light reflection has multiple stages. For surface reflection at the interface of two media, it is easy to model. For penetrating light, it is difficult to model how it interacts with the underlying material. For instance, the intermolecular interaction within a dielectric object also influences the amplitude of the dipole moment, which is hard to quantitatively factor into a model.

does it imply that the primary physical properties responsible for EM reflection are intrinsic to objects, as suggested by the SSR Thesis?

For the first question, the EM reflection mechanism clearly shows that oscillating dipoles are primarily responsible for EM reflection. Specifically, the mechanism of oscillating dipoles involved implies that oscillating dipoles are the primary causes of the reflected light, simply because the reflected light is radiated by oscillating dipoles.

The answer to the second question is no. The EM reflection mechanism implies that oscillating dipoles, as the primary causes of the reflected light, are not intrinsic to objects. The mechanism shows that oscillating dipoles arise from the light–matter interaction with incident light playing the primary role (and the material makeup playing a supportive role). First, the existence of oscillating dipoles crucially depends on the incident light. If there is no incident light, there exists no oscillating dipoles. Second, the most fundamental feature of oscillating dipoles, frequency, is determined by the frequency of the incident light in the given context. Third, the amplitude of the dipole moment is partially determined by the intensity of the incident light that induces the very charge distribution responsible for the dipole moment.[37] These points shows that oscillating dipoles are primarily determined by incident light in a given context. In short, oscillating dipoles, as the primary causes of the reflected light, are contextual events. This suggests that the primary physical properties, regardless of their nature or relation to oscillating dipoles, responsible for EM reflection are also contextual, which are not intrinsic to objects.

Besides, the above rejection of the intrinsic nature of the primary physical properties responsible for EM reflection also entails rejecting their being intrinsic dispositional properties of objects, as suggested by the SSR Thesis. Note that electrodynamics only rejects intrinsic dispositional properties, rather than dispositional properties.[38] The EM reflection mechanism suggests that assuming intrinsic dispositional properties of material objects responsible for EM reflection is ontologically extravagant. As shown above, this mechanism explains EM reflection perfectly well without invoking such intrinsic dispositional properties. Electrodynamics does not need such properties. When Maxwell discovered electromagnetism, he was fully aware of the mysterious nature and difficulties of the notion of an object's disposition or power to produce certain EM effects in some place. He wrote:

[37] See the equation of the far-away electric field produced by an oscillating dipole in this section. Although the equation is about an oscillating dipole, a qualitative analysis can be extended to most ordinary dielectric objects where there are multiple oscillating dipoles.
[38] Section 8.3 will present a version of *color physicalism that includes* dispositional properties and is compatible with electrodynamics.

> In speaking of the Energy of the field, however, I wish to be understood literally. … The only question is, where does it reside? On the old theories it resides in the electrified bodies, conducting circuits, and magnets, in the form of an unknown quality called potential energy, or the power of producing certain effects at a distance. On our theory it resides in the electromagnetic field, in the space surrounding the electrified and magnetic bodies, as well as in those bodies themselves, and is in two different forms, which may be described without hypothesis as magnetic polarization and electric polarization, or, according to a very probable hypothesis, as the motion and the strain of one and the same medium. (2010: Vol I, 564)

Figuring out the nature of the EM field is an important problem in physics.[39] The relevant point to our discussion is that Maxwell's comment on EM fields also applies to EM reflection. Namely, assuming intrinsic dispositional properties of objects to reflect light introduces a mysterious "unknown quality", which is not needed at all by electrodynamics.

Hence, Premise 3 is validated. We can conclude that if electrodynamics is true, then the SSR Thesis is false. Leaving quantum phenomena aside, electrodynamics is true. Thus, the SSR Thesis is false.

This argument may be readily apparent for some physics-oriented philosophers. However, some puzzles might still remain for color objectivists. A color objectivist might think as follows:

> Fact A: When the same incident light strikes objects of a given material type, the reflected light remains consistent.
>
> Thesis A: Fact A suggests that there is a stable way in which incident light is modified and reflected in light–matter interaction.
>
> Fact B: When the same incident light strikes objects of different material types, the reflected light is different.
>
> Conclusion: Combing Thesis A and Fact B suggests that the stable way the incident light is modified and reflected in light–matter interaction is intrinsic to the objects' material properties of a certain type.

[39] Maxwell initially assumed the existence of ether to account for the EM field. Later on, the notion of an ether is gradually abandoned due to the Michelson–Morley experiment and Einstein's relativity theories. In a more advanced framework, the EM field is considered as a gauge field in quantum field theory.

My Response. This reasoning seems quite plausible. However, when electrodynamics is considered, the above conclusion is wrong. First, this conclusion conflicts with the EM reflection mechanism. Applying this conclusion to electrodynamics entails that the EM reflection mechanism would suggest that the stable way the incident light is modified and reflected is intrinsic to the objects' material properties. This implies that both the mechanism of resonant absorption and the mechanism of oscillating dipoles would suggest so. The mechanism of resonant absorption indeed suggests a stable way the incident light is absorbed, which is intrinsic to objects. Does the mechanism of oscillating dipoles also suggest so? No. If it did, that would imply that the stable way of electrons' being induced to oscillate by light is intrinsic to the microstructural properties of objects.[40] However, this is incorrect. The EM reflection mechanism suggests that the stable way of electrons' being induced to oscillate is a matter of light-matter interaction with light playing a primary role. In particular, the frequency of the electrons' oscillations, their most essential feature, is determined by light. It follows that the way of electrons' being induced to oscillate is not intrinsic to objects. Metaphorically speaking, light leads a dance with electrons as its supportive partners, where electrons' oscillations dance to the rhythm of light, not to any rhythm intrinsic to objects. The above conclusion conflicts with electrodynamics.

Second, the reasoning of the argument is wrong. According to EM reflection mechanism, what Fact A and Fact B really suggest is that there is a stable way in which the incident light is partially absorbed in light–matter interaction, which is intrinsic to the objects' material properties of a certain type. But this stable way in which the incident light is partially absorbed is still different from the stable way in which incident light is modified and reflected, as suggested by Thesis A. It is wrong to equate these two stable ways.

Follow-up Objection.[41] Due to Fact B that different objects can reflect the same light differently: the object must have a way in the creation of oscillating dipoles, etc. It seems that all the EM reflection mechanism can show is that manifest light reflections change with circumstances, e.g., incident light, and this seems perfectly compatible with the view that SSRs are (intrinsic) dispositional properties.

My Response. The upshot of this follow-up objection is to understand oscillating dipoles as the manifestation of underlying intrinsic properties of material objects, which might well be color objectivists' notion of SSRs. First, the EM reflection mechanism suggests that it is both ontologically extravagant and inappropriate to assume intrinsic (or extrinsic)

[40] A color objectivist might further refine the point by assuming that the oscillations of electrons are manifestations of the intrinsic dispositions of objects under the right light conditions.

[41] I thank Wolfgang Freitag for this objection.

dispositional properties of material objects that is responsible for the occurrences of oscillating dipoles. As shown above, Electrodynamics explains light reflection perfectly well without invoking such dispositional properties. Specifically, the stable way of electrons' being induced to oscillate arises from light-matter interaction with light determining the electrons' oscillation frequency—their most essential feature. To be highlighted, EM reflection mechanism does not suggest that there is any intrinsic (or extrinsic) tendency of objects to alter the frequency of reflect light, which fundamentally correlates to various color perceptions. This is clearly shown by the boundary condition ($\epsilon 0E1 + P1)x = (\epsilon 0E2 + P2)x$, where P is usually related to E by $P = \epsilon E$, where ϵ is the material's permittivity, which is relative to $\epsilon 0$, the permittivity of free space. This boundary conditions plainly shows that the material's permittivity, the only role played by material in light reflection, cannot alter the frequency of reflect light. Accordingly, light is not the manifestation condition of certain underlying dispositional properties but primary inducer of oscillating dipoles. Second, the assumption that oscillating dipoles are manifestations of the dispositional property of objects under the right light conditions necessarily needs to be compatible with atomic physics, which necessarily involves quantum electrodynamics. However, the experiments on photon reflection in quantum electrodynamics shows that when we emit a single photon from a light source to a material object, we have no idea whether the photon will be reflected or be absorbed. This raises a serious challenge to the assumption that there is a way light is reflected.

3.6 The Criticism from Reflection in Quantum Electrodynamics

Quantum electrodynamics (QED) provides a scientific understanding of light reflection that is much closer to actual reality than that of spectrophotometry and electrodynamics. This section discusses the criticism from reflection in QED. Unlike the previous arguments, this criticism not only argue against the SSR Thesis, but challenges a determinist view of the reflected light that underlies the SSR Thesis, spectrophotometry and electrodynamics: given the initial conditions of the incident light and the *material structures* of the object, the state of the reflected light is predictable.

Of course, this does not mean that, due to QED, the previous arguments from spectrophotometry and electrodynamics against the SSR Thesis are useless. Quite the contrary, QED clarifies the condition under which the SSR Thesis is deemed false due to the previous arguments and thus reveals their limitations. For this reason, I use "criticism" rather than "argument" to describe what QED suggests. The criticism hinges on a proper ontological and metaphysical interpretation of photon reflection experiments in QED. The argument form of the criticism is:

Premise 1: If the SSR Thesis is true, then a determinist view of the reflected light is true.

Premise 2: Any metaphysics of light reflection is constrained by the ontological and metaphysical interpretation of the experiments on photon reflection in QED.

Premise 3: The proper ontological and metaphysical interpretation of the experiments on photon reflection in QED rules out the possibility that a determinist view of the reflected light is true.

Conclusion: It cannot be the case that the SSR Thesis is true.

The argument is valid. We examine its soundness.

Premise 1 is conceptually true. The SSR Thesis entails a determinist view of the reflected light (see above). According to the SSR Thesis, SSRs are "the proportion of incident light the object is disposed to reflect at each wavelength in the visible spectrum" (Byrne and Hilbert, 2003: 9). This implies a determinist view of *reflectance*, which means that, the reflected light is determined by the object's SSR and the incident light, where the object's SSR and the incident light are *independent* of each other. Obviously, a determinist view of *reflectance* presupposes a determinist view of the reflected light.

Note that both spectrophotometry and electrodynamics suggest a determinist view of the reflected light but does not imply a determinist view of reflectance. For instance, in the argument from reflectance in electrodynamics, the formulas for ρ_p and ρ_s suggest that the state of the reflected light is determined by the angle of the incident light and the refractive indexes of two media in a given context, where the refractive indexes depend both on the frequency of the incident light and on the material conditions of the object. This shows that the reflected light is determined by the incident light and material structures of the object (a determinist view of the reflected light) and rejects that reflectance and the incident light are independent of each other (a determinist view of reflectance).

Premise 2 is true for the following reason. Given that QED provides a more advanced scientific understanding of light reflection, if we follow the principle that any metaphysics of reflectance should be constrained by the ontological and metaphysical interpretation of the more advanced science of light reflection, it follows that Premise 2 is true.

It is worth contrasting electrodynamics with QED. First, for scope of application, QED is more comprehensive. Electrodynamics breaks down at the quantum level and cannot account for many quantum phenomena. In contrast, QED can, in a rough sense, describe "all the phenomena of the physical world except the gravitational effect" (Feynman 1988: 8).[42] Second, QED is more fundamental than electrodynamics, which can be seen as a non-quantum approximation of QED. When quantum effects are negligible, QED simplifies to electrodynamics; otherwise, quantum corrections to electrodynamics are necessary.[43]

Premise 3 is the crux of the argument. It states that, according to the proper ontological and metaphysical interpretation of the experiments on photon reflection in QED, a determinist view of the reflected light is not true.

What are the experiments on photon reflection in QED? There are many experiments on photon reflection, among which the experiment of *the partial reflection of light* is the most basic one. In what follows, I only focus on this experiment: [44]

> As illustrated by Figure 3.5, photons of monochromatic light are emitted from a light source to a piece of glass at perpendicular angle. Outside the glass there is a photomultiplier A to detect reflected photons; inside the glass, there is a photomultiplier B to detect photons transmitted into the glass. In the event, out of 100 photons emitted, 4 photons are reflected and detected by A, 96 photons are transmitted into the glass and detected by B.

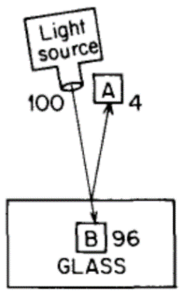

Figure 3.5: Partial reflection of light.[45]

The experiment suggests that photon reflection is partial. In this case, 4% of the photons are reflected and 96% of the photons are transmited into the glass. What does "partial reflection"

[42] "In a rough sense" means that when it comes to simple cases with just a few electrons, we can calculate the results of an experiment accurately with QED, but when it comes to cases with many electrons, the complexities prohibit an accurate quantitative analysis (Feynman 1988: 8).
[43] The point is also shown by the development from electromagnetic theory to quantum electrodynamics. "Maxwell's theory of electricity and magnetism had to be changed to be in accord with the new principles of quantum mechanics that had been developed. So a new theory, the quantum theory of the interaction of light and matter, which is called by the horrible name 'quantum electrodynamics', was finally developed by a number of physicists in 1929" (Feynman 1988: 6).
[44] Other experiments are variations on the experiment on the partial reflection of light. See Feynman 1988.
[45] The picture is from Feynman 1988: 17.

of photons mean? "How can light be *partly* reflected? Each photon ends up at A or B—how does the photon 'make up its mind' whether it should go to A or B? … Partial reflection is already a deep mystery" (Feynman 1988: 18).

Feynman summarizes the situation as follows: "Here is a circumstance—identical photons are always coming down in the same direction to the same piece of glass—that produces different results. We cannot predict whether a given photon will arrive at A or B. All we can predict is that out of 100 photons that come down, an average of 4 will be reflected by the front surface" (1988: 19).

Many attempts have been made to explain the partial reflection of light on the basis of a determinist notion of the reflected light, and all have failed.[46] Hence, this experiment suggests that there is an intrinsic indeterminacy in whether or not a photon will be reflected by a piece of glass.

What does this intrinsic indeterminacy of single photon reflection in QED mean?

Feynman puts it like this: "Does this mean that physics, a science of great exactitude, has been reduced to calculating only the *probability* of an event, and not predicting exactly what will happen? Yes, that's retreat, but that's the way it is: Nature permits us to calculate only probabilities" (1988: 19). "I will only show you how to calculate the correct *probability* that light will be reflected from glass of a given thickness, that's the only thing physicists know how to do! What we do to get the answer to *this* problem is analogous to the things we have to do to get the answer to *every other* problem explained by quantum electrodynamics" (1988: 24). Put another way, what QED cannot tell us is whether or not a specific event will happen. It can only tell us the calculated probability of an event under certain conditions, which is well supported by the empirically established statistical results.

Back to the discussion of Premise 3. What does the proper ontological and metaphysical interpretation of the experiment of the partial reflection on light?

The metaphysical interpretation of the results of this experiment is that there is an intrinsic indeterminacy in single photon reflection. It follows that it is neither that the reflection of a photon is determined by the reflectance and the incident photon, nor that a

[46] In his lecture, Feynman (1988) mentions two failed explanation attempts. The first attempt is to say that "96% of the surface of the glass is 'holes' that let the light through, while the other 4% of the surface is covered by small 'spots' of reflective material" (1988: 18). This explanation is debunked by an experiment where, as the thickness of the glass changes, the portion of reflected photons changes in a repeating cycle (1988: 20–22). The second attempt is to say that "the photons have some kind of internal mechanism—'wheels' and 'gears' inside that are turning in some way—so that when a photon is 'aimed' just right, it goes through the glass, and when it's not aimed right, it reflects" (1988: 18). This explanation is falsified by a related experiment: If many filters are arranged between the light source and the first layer of glass to single out the "correctly" aimed photons, then it is expected that *all* photons are aimed right and none of them should be reflected. However, the result is that still 4% of the correctly aimed photons are reflected (1988: 18–19).

reflected photon is determined by the material structure of object and the incident photon. This suggests that neither a determinist view of reflectance nor a determinist view of the reflected light is true.

What does the proper ontological interpretation of the experiment on the partial reflection of light suggest about the ontology of reflectance?

My answer is that it makes plausible that anti-realism about reflectances is the proper ontological view of reflectance. Obviously, given the intrinsic indeterminacy of single photon reflection, it is straightforward and reasonable to endorse anti-realism about reflectance: reflectance does not exist.[47]

Hence, Premise 3 is validated. We can conclude: it cannot be the case that the SSR Thesis is true.

This conclusion differs from the previous ones in Sections 3.2–3.5. It asserts that it *cannot* be the case that the SSR Thesis is true, rather than, that for most ordinary objects, SSRs are not illumination-independent properties (see Section 3.2), SSRs are not illumination-independent properties (see Sections 3.3–3.4), or if electrodynamics is true, then SSR Thesis is false (see Section 3.5). The difference lies in the ontological interpretation of reflectance. In the previous arguments, even if there is some room for anti-realism about reflectances (that is, to deny the existence of reflectances), I assumed realism to avoid unnecessary complexities. The reflectance concept is typically used with a deterministic, realist commitment. There is no difference between concluding that it cannot be the case that the SSR Thesis is true and the other conclusions. However, due to QED, anti-realism about reflectances enters the arena. In this context, anti-realism is straightforwardly reasonable, while realism is not. QED offers no clear reason to abandon anti-realism about reflectances, but clearly supports abandoning certain realist views, such as the SSR Thesis. Thus, an important distinction exists between concluding that it cannot be the case that the SSR Thesis is true and the other conclusions; the former allows for anti-realism about reflectances.

One last remaining point. According to QED, under what conditions the SSR Thesis is deemed false due to the previous arguments? The answer is that the SSR Thesis is false when the photons of light are not understood as quantum objects.

[47] I should emphasize that I do not claim that, regarding the above criticism, anti-realism about reflectances is the most plausible or the correct view of reflectances. This would involve the metaphysics of quantum mechanics and quantum field theory, which is a different debate. I only claim that, given the above criticism, anti-realism about reflectances is a straightforward and reasonable choice.

3.7 The Objectivists' Misunderstandings of Reflectance

The previous sections show that the reflectance concept in science constrains any metaphysics of reflectance and that the SSR Thesis is false. Given that the SSR Thesis is based on color science (see Section 3.3), this implies that the color objectivists must have misunderstood the reflectance concept in color science. This section will unravel this misunderstanding, namely, Byrne and Hilbert's misunderstandings of the reflectance concept employed by Judd and Wyszecki in spectrophotometry in color science.

Byrne and Hilbert (2003) rely solely on Judd and Wyszecki's (1975) work to support their SSR Thesis. There is no direct citation in Byrne and Hilbert' paper. They only mention Judd and Wyszecki's definition of reflectance in a footnote: "For precise definitions of 'reflectance' and 'reflectance factor', see Judd and Wyszecki (1975, p. 463)" (2003: footnote 24). This detail is important. It indicates that Byrne and Hilbert's understanding of reflectance faithfully follows Judd and Wyszecki's work, making their SSR Thesis a natural consequence that requires no further argument.

My remarks about this misunderstanding may be obvious to some scientifically driven philosophers. However, since doubts about the SSR Thesis are rare in the literature, it is important to stress the need for a solid understanding of the science of reflection.[48] Accordingly, it is worthwhile to present Judd and Wyszecki's notion of reflectance in detail. The remaining section unfolds as follows: First, I will introduce Judd and Wyszecki's notion of reflection. Second, I will discuss three misunderstandings of Byrne and Hilbert's. Third, I will discuss the systematic nature of these misunderstandings.

[48] As has been mentioned in footnote 1 of this chapter, Danne's "How to Make Reflectance a Surface Property" (2020) is the only attempt I find in the color debate to question the metaphysics of reflectance assumed by reflectance physicalists. Danne's argument is based on the electromagnetic field theory of light. In this paper, Danne argues that the Hilbertian SSR is "not a surface property, but a combination property of surface-and-medium or surface-and-light" (2020: 1). Danne's argument relies on a fine-grained understanding of the propagation of electromagnetic radiation in reflection processes and on "an ontology of (Fourier) harmonics as entities literally reflecting from surfaces" (2020: 3). The Hilbertian concept of SSRs fails to consider the harmonical component of electromagnetic radiation in reflection processes, which is a "well-documented, empirical phenomenon" (2020: 2). "Harmonics" refers to "the tendency of an electromagnetic pulse, which propagates at a dominant carrier or center frequency, to propagate at more than one frequency when pulse durations become extremely short" (2020: 6). Danne argues that, if we take into account the harmonical component, a certain mathematical realism is required, in the sense that mathematical facts (Fourier analysis) can explain physical facts (the harmonical component of electromagnetic radiation in reflection processes). My consideration of reflectance is quite different from Danne's. My discussion is based on nothing more than what reflectance physicalists allow for. Danne's route is based on the electromagnetic field theory of light, which is more advanced than the wave theory of light employed by reflectance physicalists. The price for this is that Danne's route introduces a new problem related to mathematical realism. Despite the price, this is still progress. Besides, although our routes are quite different, my conclusion is similar to Danne's: that the metaphysics of reflectance assumed by reflectance physicalists is incorrect, and that the appropriate metaphysical interpretation of reflectance is that it is "not a surface property, but a combination property of surface-and-medium or surface-and-light" (2020: 1).

According to Judd and Wyszecki, in a color measurement regarding an opaque object, the property to be measured in the first place is the spectral reflectance factor (SRF).[49] Defining SRF demands a proper scientific understanding of light reflection. Judd and Wyszecki write:

> The definition of spectral reflectance factor ß(λ) is more complex because it takes account of the fact that reflecting properties of an opaque object *depend much upon the way object is illuminated and viewed* … Part of the radiation flux incident on the surface is reflected in some more or less good approximation of *an image forming state*; the remainder penetrates the surface, and, after suffering absorbing, scattering, and multiple reflection beneath the surface, it is reemitted in *a nearly diffuse state*. (1975: 92–93; emphasis added)

On this understanding, in the case of opaque objects, all reflection is more or less specular. Importantly, both the diffuse and the specular component are integral parts of reflection. The definition of SRF must involve the specular component of reflection. Otherwise, the definition is implausible. Given this understanding of light reflection, Judd and Wyszecki give their definition of SRF:

> All diffusing materials and articles of commerce fail to be perfectly mat; that is, they exhibit more or less gloss. … It is appropriate to assess the reflecting properties of an opaque object relative to the perfect reflecting diffuser identically illuminated and viewed and a formal definition of SRF may then be given as follows:
>
> The spectral reflectance factor, ß(λ), of an object is the ratio of the spectral radiant flux reflected in the directions delimited by a given cone whose apex is at a given point on the surface of the object, to the spectral radiant flux reflected in the same directions by the perfect reflecting diffuser identically illuminated. (1975: 93)

It is important to understand the role of the concept of a perfect reflecting diffuser in defining SRF. In color measurements with a spectrophotometer, it is not necessary to measure the absolute value of the reflected flux or the incident flux. "The actual spectral distribution of radiant flux provided by the source is of no concern to us, since only flux ratios are measured

[49] "The fundamental properties of an object responsible for its color are spectral transmittance for transparent objects and spectral reflectance factor for opaque objects" (Judd and Wyszecki 1975: 92).

by the instrument at the various wavelengths" (1975: 95). Given that only flux ratios are measured and that the specular component of reflection must be somehow factored in, the concept of a perfect reflecting diffuser is theoretically designed as a part of the definition of SRF in order to meet this constraint. A "perfect reflecting diffuser" is an object that reflects the incident light in all directions uniformly without loss. If the concept of a perfect reflecting diffuser is satisfiable or if some objects are good enough to be conventionally accepted as perfect reflecting diffusers, then the amount of the specular component of reflection for a tested object can be evaluated by a comparison with that of a (quasi-)perfect reflecting diffuser under the same illumination conditions. Unlike philosophers, color scientists are not bothered by whether or not the concept of perfect reflecting diffusers is satisfiable. Even if it is not, a conventionally accepted standard for perfect reflecting diffusers is sufficient for color science.[50]

Judd and Wyszecki further illustrate the formula for SRF with the following diagram (see Figure 3.6).

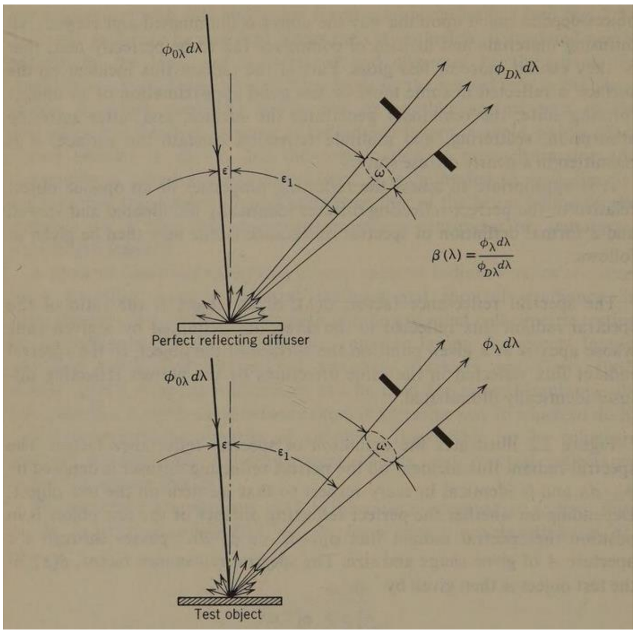

Figure 3.6: A schematic diagram for measuring SRF ß(λ).[51]

The spectral radiant flux incident on the perfect reflecting diffuser is denoted by $\Phi_{0\lambda}$ dλ and is identical in every respect to that incident on the test object. Depending on whether the perfect reflecting diffuser or the test object is in position, the spectral radiant flux

[50] According to Judd (1952: 83), a magnesium oxide reflectance standard has conventionally been accepted by many (Keegan, 1939; TAPPI Spec. T633m-47; ASTM Method D 985-48T).
[51] See Judd and Wyszecki 1975: 94.

$\Phi_{D\lambda}$ dλ or Φ_{λ} dλ passes through the aperture A of given shape and size. The spectral reflectance factor, ß(λ), of the test object is then given by ß(λ) = $\frac{\Phi_{\lambda}^{(\omega)} d\lambda}{\Phi_{D}^{(\omega)} d\lambda}$. (1975: 93)

Finally, they extend this definition of SRF to two limiting cases. In one limiting case, the definition of *spectral reflectance* is derived from the definition of the spectral reflectance factor:

> There are two limiting cases for the spectral reflectance factor with regard to the size of the cone delimiting the reflected spectral radiant fluxes. … If the solid angle of the cone approaches 2π (hemisphere above the test object), the spectral reflectance factor is called spectral reflectance and denoted by ρ(λ). By definition, the perfect reflecting diffuser reflects all the incident radiant flux $\Phi_{0\lambda}$ dλ in all directions uniformly without loss. It then follows that the spectral reflectance ρ(λ) of a test object is simply the ratio of the spectral radiant flux Φ_{λ} dλ reflected into the hemisphere above the test object to the incident spectral radiant flux $\Phi_{0\lambda}$ dλ; thus ρ(λ) = $\frac{\Phi_{\lambda}^{(\omega=2\pi)} d\lambda}{\Phi 0\lambda \, \mathrm{d}\lambda}$. (1975: 93–94)

In brief, the spectral reflectance is the ratio of the reflected spectral flux to the incident spectral flux. In Judd and Wyszecki's theory, the definition of the spectral reflectance is entailed by the definition of SRF on the conditions that "the solid angle of the cone approaches 2*π*" and that the concept of a perfect reflecting diffuser is satisfiable or adopted. Put another way, even if the concept of a perfect reflecting diffuser did not appear in the definition of spectral reflectance, the definition actually presupposes the satisfiability of the concept of a perfect reflecting diffuser.

So much for the introduction of Judd and Wyszecki's notion of reflection. Next, I will discuss three misunderstandings Byrne and Hilbert fall prey to.

The first misunderstanding is about the specular component of reflection. Judd and Wyszecki's notion of reflection is premised on the condition that the specular component of reflection is factored in. By contrast, Byrne and Hilbert assume that it is in principle allowable in their notion of reflectance to ignore the specular component. "Throughout we will adopt the idealization of ignoring the specular (mirror) component of the reflectance. The component of the reflectance that is of interest to us is the body reflectance, which carries more information about the material properties of the reflecting surface" (Byrne and Hilbert

2003: footnote 23). Byrne and Hilbert (2003, 2021) do not give any explanation for why they think it is allowable to ignore the specular component.[52]

As clearly shown, in Judd and Wyszecki's work the specular component of reflection is tackled head-on by means of some further theoretical constructions. The whole point of Judd and Wyszecki's definition of reflectance is to factor in the specular component, based on the fact that "[p]art of the radiation flux incident on the surface is reflected in some more or less good approximation of an image forming state" (1975: 93). Thus, the specular component is intrinsic to the definition of reflectance such that, in principle, it cannot be ignored. Therefore, it is a misunderstanding to assume that the specular component of reflection in Judd and Wyszecki's definition of reflectance can in principle be ignored.

The second misunderstanding pertains to the directional dependence of spectral reflectance. According to Judd and Wyszecki's notion of reflection, the definition of the spectral reflectance is entailed as a limiting case by the definition of SRF. The definition of SRF, $ß(\lambda) = \frac{\Phi_{\lambda}^{(\omega)} d\lambda}{\Phi_{D}^{(\omega)} d\lambda}$, plainly shows that SRF is direction-dependent.[53,54] It follows that the spectral reflectance is also direction-dependent. In comparison, Byrne and Hilbert assume that the surface spectral reflectance (SSR) is the average of the object's reflectance factor measured in all directions and that it is direction-independent.[55] "In the standard account of reflectance – the one adopted here – it is the average of the reflectance measured in all directions (i.e., the average, over all directions δ, of the object reflectance factor at δ). Because reflectances are not direction-dependent, this has the result that on the theory of color

[52] It is hard to guess at the underlying reasoning. It might be that, first, it is intuitive to associate the body reflectance (or "the diffuse component of reflection") with stable colors of objects captured in a certain phenomenological sense; second, if one attempts to theoretically identify colors with the diffuse component of reflection, then the latter must be individuated under certain individuation conditions; third, the diffuse component of reflection can be individuated by assuming that it is just the spectral reflectance; fourth, the diffuse component of reflection is just the spectral reflectance only if the specular component of reflectance can be ignored.

[53] The point is also made explicit by Judd and Wyszecki: "… it can be readily be deduced that its value depends to a large extent upon the direction of illumination, ε, the direction of viewing, ε_1, and solid angle ω of the cone determined by the size and distance of aperture A, particularly when the test object has a glossy surface. For example, if ε_1 is equal to ε and ω is small, the spectral reflectance factor ß(λ) may have a value much larger than unity because the cone may contain the mirror image of the source" (1975: 93).

[54] One can make the stronger claim that the spectral reflectance factor is context-dependent. For a given point on a surface in a given context, there are numerous directions from which beams of incident light strike that point, numerous directions from which the point can be viewed, numerous distances in one direction from which the point can be viewed, and numerous solid angles at a certain distance in a certain direction from which the point is viewed. All these factors make the value of the spectral reflectance factor highly context-dependent.

[55] There is a minor difference between Judd and Wyszecki's definition of spectral reflectance and Byrne and Hilbert's definition of SSR. The former applies to a point while the latter applies to a surface. If the physical make-up of a surface is isotropic, then the two are the same. For natural objects, such as apples, there can be variations in the make-up of a surface. It is reasonable to doubt Byrne and Hilbert's definition of SSR regarding this point. However, for the sake of simplicity, we ignore the problems associated with variations in a surface area.

proposed below, objects like peacocks' tails will often produce color illusions" (2003: footnote 24). Obviously, this understanding is wrong. The reasoning underlying their belief in the direction-independence of reflectance seems to be that, since the SSR is the average of the object reflectance factor measured in all directions, it follows that the SSR is direction-independent. This reasoning is wrong. Measuring the SRF of an object in all directions does not make the SSR direction-independent. Instead, the correct conclusion is that the SSR is direction-dependent in the sense that it depends on all directions!

The third misunderstanding concerns the concept of a perfect reflecting diffuser. According to Judd and Wyszecki, the definition of SRF presupposes the satisfiability of the concept of a perfect reflecting diffuser. By contrast, Byrne and Hilbert's definition of SSR suggests that it can work without this concept. This is incorrect. Discussing of the satisfiability of the concept of a perfect reflecting diffuser is inevitable for Byrne and Hilbert. Their definition of SSR actually presupposes the satisfiability of this concept. First, as shown in the argument from the perfect reflecting diffuser (see Section 3.2), SSR conceptually entails this satisfiability. Moreover, the entailment relation between the concepts of SSR and SRF also presupposes this satisfiability. As mentioned, on Byrne and Hilbert's definition, the SSR is "the average of the reflectance measured in all directions (i.e., the average, over all directions δ, of the object reflectance factor at δ)" (2003: footnote 24). As discussed, the concept of a perfect reflecting diffuser means an object that reflects the incident light in all directions uniformly without loss. If this concept lacks satisfiability, then there is no common denominator, $\Phi_{\mathrm{D}}^{(\omega)} d\lambda$, for different SRFs, $ß(\lambda) = \frac{\Phi_{\lambda}^{(\omega)} d\lambda}{\Phi_{\mathrm{D}}^{(\omega)} d\lambda}$. Accordingly, it is impossible to calculate an average of SRF. Hence, the belief that the definition of SSRs can work without the satisfiability of the concept of a perfect reflecting diffuser is incorrect.

Finally, I will discuss the systematic nature of these misunderstandings. They are not random, arbitrary and unmethodical, but rather systematic, consistent and methodical. They all arise from the same assumption: SSRs are intrinsic properties of objects such that physical colors are SSR-related properties of objects, which is the thesis (a2) of reflectance-grounded objectivism (see Section 1.2). SSRs, as intrinsic properties, must be illumination-independent. Accordingly, any phenomenon or scientific concept of reflectance that conflicts with the illumination-independence of SSR must be ignored or adjusted to align with it. Thus, when it comes to the specular component of reflection, what cannot be ignored is overlooked. When considering the direction-dependence of reflectance obviously suggested by spectrophotometry, the opposite claim is made. When the concept of a perfect reflecting diffuser suggests that reflectance is direction-dependent, there is no response. In sum, since the SSR Thesis is tailored so as to fit color objectivism, especially reflectance-grounded objectivism, these systematic misunderstandings are inevitable.

Byrne and Hilbert conclude their paper with the following claim: “Some color scientists would complain that physicalism does not respect science enough. Proper attention to the facts of color vision, they would say, shows that colors are really ‘in the brain.’ … We have tried to counteract this tendency … At the very least, physicalism should be taken more seriously by color scientists” (2003:19). However, as demonstrated in Sections 3.2–3.7, the issue is not that reflectance physicalism lacks respect for science, but that it fundamentally *misunderstands* science.

Given the falsity of the SSR Thesis, how could reflectance physicalism be a plausible view of color if its metaphysics of reflectance is wrong in the first place? As we will see in Section 3.8, the falsity of the SSR Thesis results in many consequences.

3.8 Consequences

As demonstrated, the arguments from Sections 3.2–3.5 show the falsity of the SSR Thesis. This has some consequences that will profoundly shape the ongoing discussion. I address five such consequences.

First, reflectance physicalism is false. As discussed in Section 2.2, if reflectance physicalism is true, then the SSR Thesis is true. As demonstrated, the SSR Thesis is false. It follows that reflectance physicalism is false.

Second, other main versions of color objectivism are just false. Since all main versions of reflectance-grounded objectivism share the SSR Thesis and the SSR Thesis is false, all these versions are false. Specifically, in Section 7.1, I reject microstructure physicalism; in Section 7.2, I dispute color primitivism.

To demonstrate the falsity of color-disposition-grounded objectivism, further aspects need to be addressed. As discussed in Section 1.2, the proponents of this approach differ on the most promising candidate for the realizer of a color disposition but believe that their conceptual framework is well designed to accommodate the as-yet-unspecified candidate (pending empirical evidence from science). I have partially covered this topic in Section 3.5 by hinting that “as-yet-unspecific candidate” has no sense because electrodynamics has shown that oscillating dipoles are good candidates responsible for light reflection as well as the color appearance of an object. I will further argue in Chapter 8 that the conceptual framework of color-disposition-grounded objectivism conflicts with the conceptual framework of light reflection in electrodynamics.

Third, the argument for the Color Thesis is necessarily unsound. As discussed in Section 2.4, if the SSR Thesis is false, the following thesis holds:

> *The Unsoundness of the Argument for the Color Thesis:* Whatever reflectance physicalists' non-reflectance-related argument for the Color Thesis is, the argument is unsound.

Accordingly, we can reject the Color Thesis without engaging in any debate regarding the four premises for the Color Thesis: the causal premise, the phenomenological premise, the premise from representationalism and the vision science premise. The conclusion of these premises is necessarily false.

In the literature, most objections to reflectance physicalism bear either on the specific premises for the view or on its epistemological and phenomenological consequences. These objections actually assume the truth of the SSR Thesis in the first place. By contrast, this chapter has shown that the SSR Thesis is false. Given its falsity, the Color Thesis as such has no chance of being right. That is, we can reject the Color Thesis without examining any non-reflectance-related argument reflectance physicalists might adduce for the Color Thesis.

If the aim were merely to show the falsity of the Color Thesis, I could simply stop here. However, to know the falsity of a view is one issue, to find out the specific mistakes that engendered the belief in the false view is a different and more challenging task. Indeed, identifying the mistakes in reflectance physicalism will clarify our understanding of it. This is exactly what I will do in the rest of Part I.

Fourth, two kinds of mistake regarding the Color Thesis are possible: errors in reasoning when deriving the Color Thesis from the premises, and mistakenly accepting one or more of the premises. The first kind of mistake indicates unsound reasoning, where the premises and conclusion are mutually exclusive. Accordingly, Chapter 4 is precisely about the mutual exclusiveness between the Color Thesis of reflectance physicalism and representationalism. For the second kind of mistake, there are mistakes regarding particular premises, as discussed in Chapter 5 and Chapter 6.

Fifth, some previously discussed arguments suggest where to look for mistakes in the premises for the Color Thesis.

For one point, the argument from the perfect reflecting diffuser, the argument from reflectance in spectrophotometry and the argument from reflectance in electrodynamics target the illumination-independence of SSR, which suggests that mistakes can arise concerning the premise related to the *illumination-independence of color*. Reflectance physicalists establish the illumination-independence of color via the premise from representationalism (see Section 2.2).[56] Specifically, this premise depends on properly characterizing color constancy and the truth of representationalism, so mistakes must lie in one or both of these areas. Accordingly, in Chapter 5, I discuss the mistakes related to representationalism; in Sections 7.4 and 7.5, I focus on the mistakes related to the characterization of color constancy, which is a pillar of reflectance physicalism and common to all main versions of reflectance-grounded objectivism.

For another point, the argument from the reflection mechanism in electrodynamics suggests that the cause of the reflected light is oscillating dipoles, which indicates that there might be mistakes in the causal premise. Accordingly, in Chapter 6, I address two problems of this premise.

[56] Recall Byrne and Hilbert's claim that "color vision of human beings and many other organisms exhibits approximate color constancy, … for instance, tomatoes do not seem to change color when they are taken from a sunny vegetable patch into a kitchen illuminated with incandescent light. Assuming that our perceptions of color are often veridical, we therefore need a physical property of objects that is largely illumination-independent – a physical property that an object can retain through changes in illumination" (2003: 9).

4

Mutual Exclusiveness

The previous chapter rejects the Color Thesis of reflectance physicalism without engaging in any debate regarding the four premises for the thesis (see Section 3.8). From this chapter onward, I will begin identifying the mistakes related to the Color Thesis. This chapter will show that reflectance physicalism and representationalism (as figuring in a premise of the view; see Section 2.2) are mutually exclusive. Specifically, the combination of the two theses fails to account for simultaneous color contrast, a ubiquitous phenomenon. Accordingly, the two theses cannot both be true.

The chapter has the following structure: In Section 4.1, I assess the combination of reflectance physicalism and representationalism. Section 4.2 presents the argument from mutual exclusiveness, according to which the above combination is falsified by simultaneous color contrast. Section 4.3 formulate a more precise definition of simultaneous color contrast. In Section 4.4, I will respond to Byrne and Hilbert's objection that simultaneous color contrast can be dismissed because it is a color illusion. In Section 4.5, I will rebut Tye's objection that simultaneous color contrast can be sidelined because it is an intentional inexistent.

4.1 An Internal Combination

What is the relation between representationalism and reflectance physicalism? As discussed in Section 2.2, representationalism is established independently of reflectance physicalism, with the latter, in turn, incorporating the former as one of its premises. Notably, in the literature, representationalism is often paired not just with reflectance physicalism, but with color objectivism in general.

On the one hand, color objectivism needs representationalism. For instance, Jackson claims:

> Colours are as objective as shapes. Representationalism about perceptual experiences – the view that perceptual experiences represent that things are thus and so, and that their doing so is at least part of what makes them the kinds of experiences they are – tells us this. (2019: 819)

Conversely, representationalism needs color objectivism. As discussed, representationalism is the view that perceptual experiences represent external states of affairs by their representational contents. The phenomenal characters of perceptual experiences are determined by (or identical with, or grounded in) their representational contents in the sense that "[t]he representational content of a subject experience specifies the way the world appears to the subject (Byrne and Hilbert, 2003: 5)". And the veridicality or non-veridicality of representational contents is determined by external states of affairs. Given these points, it is clear that phenomenal characters ultimately depend on the external properties of the environment, including the external color properties. This implies that representationalism needs color objectivism. For instance, William Lycan claims:

> [T]he Representational theory requires color realism, for it explicates color qualia in terms of the real- (and unreal-) world colors of physical objects; "yellow" means the objective, public property inhering in physical objects. One could not then turn around and explicate the ostensible colors of physical objects in terms of color qualia (e.g., as the disposition to produce yellow qualia in normal human percipients). (2001: 20)

In the literature, reflectance physicalism is the version of color objectivism most commonly paired by representationalism.[1] One reason might be that both views are reductionist theories, making it possible to strengthen the combination in a reductionist framework of color and color perception.[2]

Still, acknowledging the potential for the combination is one thing. Confirming the compatibility of the two views requires further examination. Are they compatible in the first place?

In the literature, several objections can be identified that indicate the problems of the combination. These objections can be roughly classified into three kinds. The first kind supports that the combination is unable to account for the structural relationship between colors.[3] The second kind upholds that the combination is unable to account for the

[1] For representationalists, another possible counterpart is color primitivism. However, color primitivists are typically not representationalists. Instead, they typically hold primitivism about perception, the view that perceptual experiences are constituted by the primitive properties of objects.
[2] See Tye 1995, Dretske 1995 and Byrne and Hilbert 2003. Note that Lewis (1997) does not explicitly endorse representationalism, but he explicitly endorses both reductionism about color experience and reflectance physicalism.
[3] See Hardin 1988, Maund 1995, Thompson 1995 and Adam Pautz 2006, 2021.

phenomenal characters of color hallucinations.[4] The third kind reinforces that the combination makes wrong predictions in the case of perceptual color representation.[5]

The first kind of objection relies on the metaphysical assumption of the structural relationships between colors, such as that red is more similar to yellow than to green. This objection requires the existence of color structures, which is a controversial issue.[6] Regarding the second objection, it seems that reflectance physicalists can respond sufficiently For instance, to account for how a hallucinatory experience can have a phenomenal character, reflectance physicalists might appeal to an awareness of non-instantiated universals in the hallucinatory experience.[7] To counter the third objection, reflectance physicalists might claim that the methodological assumption underlying the chosen criteria for predictions misses the centrality of reflectance physicalism.[8]

My objection is of a fourth kind. It differs from the previous ones because it does not rely on any additional theoretical (metaphysical, epistemological, semantic or methodological) assumptions. It only calls for considering a ubiquitous phenomenon, namely simultaneous color contrast.

4.2 The Argument from Mutual Exclusiveness

The argument goes as follows:

Premise 1: If both representationalism and the Color Thesis of reflectance physicalism are true, then phenomenal colors supervene on physical colors.

Premise 2: It is not the case that phenomenal colors supervene on physical colors (because the supervenience relation is falsified by simultaneous color contrasts).

Conclusion: Representationalism and the Color Thesis cannot both be true.

[4] See Laura 2017.
[5] See Mendelovici 2018: Ch. 3.
[6] For objections, see Hardin 1988, 66 and Boghossian and Velleman 1991. For responses, see Cohen 2003 and Byrne 2003.
[7] For instance, see Tye's answer: "Agreed: you cannot attend to what is not there. But on my view, there is an un-instantiated quality there in the bad cases … an un-instantiated quality is present in hallucination" (Tye 2014: 51).
[8] In her objection to representationalism, Mendelovici appeals to the existence of certain perceptual states where there are perceptual color representations in which "we notice nothing to do with specific surface reflectance profiles" (2018: 40). This suggests that the view fails to predict what perceptual color representations represent in the case of sky-blue. Reflectance physicalists might respond that this is not a fair objection, since they only focus on the case of ordinary material objects, like apples. Or reflectance physicalists might claim that given that the sky consists of air molecules, when a certain volume of air molecules is chosen, it has an SSR that can be represented.

The argument is valid. We examine its soundness. For Premise 1, some terminology needs to be clarified, including "phenomenal colors", "physical colors" and "supervenience".

What are phenomenal colors? Different philosophers might reserve the term for different uses. Here, for reasons of charity, I adopt Byrne and Hilbert's use: "If we stress the appropriateness of color terms, then the things to be distinguished are certain salient properties represented by those experiences (e.g., the salient surface property the tomato visually appears to have). These properties are sometimes called phenomenal colors, or colors-as-we-see-them" (2003: 6). On this use, phenomenal colors are salient surface properties objects appear to have.

What are physical colors? Philosophers tacitly use "physical colors" in different ways. Again, out of charity, I adopt Byrne and Hilbert's use: "the optical properties of an object are responsible for its appearance of color – sometimes called physical color. Colorimetry is largely concerned with physical color; and so the chromaticity and purity of a light source can be said to be measures of its physical color" (2003: 6). On this use, physical colors are intrinsic properties of objects that are responsible for the color appearances they elicit.

What is the supervenience relation between phenomenal colors and physical colors? The idea of a supervenience relation is that *A* supervenes on *B* just in case there cannot be a difference in *A* without a difference in *B*. In the current context, the supervenience relation is cashed out as follows: phenomenal colors supervene on physical colors in the sense that there cannot be a difference in the former without a difference in the latter. Given the above clarifications of phenomenal colors and physical colors, "the supervenience relation" means that there cannot be a difference in the salient surface properties an object like a tomato visually appears to have without a difference in its SSR.

With these clarifications, one can ask: do reflectance physicalists agree with Premise 1? Note that Premise 1 is formulated as a conditional. To answer the question, one needs to examine whether the antecedent entails the consequent, that is, whether the combination of reflectance physicalism and representationalism entails that phenomenal colors supervene on physical colors. The following three points will demonstrate this: (i) phenomenal colors are represented colors, (ii) represented colors are physical colors (in standard cases), and (iii) identity entails supervenience.

For Thesis (i), it is confirmed by Byrne and Hilbert's clarification and is also presupposed by the representationalists' phenomenology. According to Byrne and Hilbert, phenomenal colors and represented colors mean the same. When the term "colors" is used without any additional modifications, it refers to phenomenal colors. For instance, "Do the objects that appear to have phenomenal colors really have them? Accordingly, whenever 'color' occurs unmodified in this article, it means phenomenal color" (2003: 6). And when the term "colors" is used in representationalism, it refers to represented colors. For instance, "And what is the property red that figures in the content of such experiences? … Colors, at any rate in the sense in which they concern us in this article, are (at least) properties represented by certain kinds of visual experiences" (2003: 5).

Besides the above point, (i) was already mentioned in Section 2.2. Namely, representationalism involves a way of understanding the phenomenology of perceptual experience: phenomenology is nothing over and above representational content. Accordingly, phenomenal colors are just represented colors.

For Thesis (ii), it is given by reflectance physicalism. As discussed, the Color Thesis of reflectance physicalism is established by four premises, with the premise of representationalism as a key part. This is crucial for guaranteeing the identity of represented colors with physical colors (in standard cases).

Combining (i) and (ii), it follows that phenomenal colors are identical with physical colors. To situate it within a posteriori physicalism, phenomenal colors and physical colors are ultimately proved to be the same thing. As Byrne and Hilbert claim, "[b]ut here's the important point: rather paradoxically, a distinction may turn out not to distinguish anything! At the start of inquiry, one would want to make a distinction between salt and sodium chloride, or the butler and the murderer, even though it may turn out that salt *is* sodium chloride or that the butler *is* the murderer. It may similarly turn out with phenomenal color and (a kind of) physical color. Although care must be taken to make this distinction at the outset, perhaps phenomenal and physical color are one and the same" (2003: 6; italics in the original).

For Thesis (iii), it is conceptually true.

Combining (i), (ii) and (iii), it follows that due to the identity of phenomenal colors with physical colors, the former supervene on the latter in the sense that there cannot be a difference in the former without a difference in the latter. Reflectance physicalists therefore must agree with Premise 1.

Premise 2 claims that, due to simultaneous color contrast, it is *not* the case that phenomenal colors supervene on physical colors. To validate it, we first need to establish a criterion for examining such supervenience relations. The identity claim carries a modal force that can be specified in terms of metaphysical necessity.[9] This modal force also applies to the

[9] For the sake of simplicity, I here neglect the distinction between metaphysical necessity and nomological necessity. Note that the argument still works in a similar way even if we make this distinction. The upshot is that the complexities associated with different notions of modality are not crucial in this context. Thus, we can work with a simplified assumption.

related supervenience relation. Consequently, we have the thesis that phenomenal colors necessarily supervene on physical colors. This *supervenience thesis* is useful for examining the combination of reflectance physicalism and representationalism, since it allows a single counter-example to show the falsity of the combination: if there is a single case where there is a difference in phenomenal colors without a difference in physical colors, then the combination is false. Figure 4.1 shows such a case.[10]

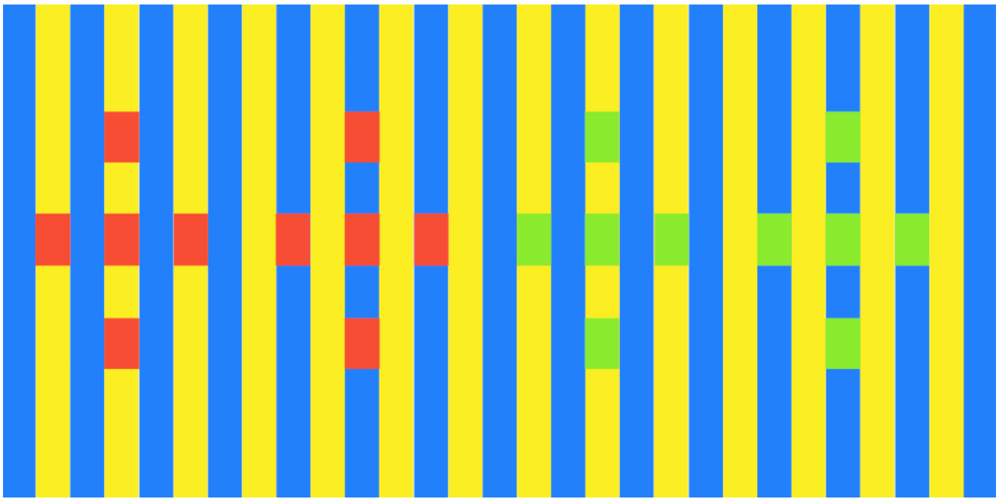

Figure 4.1: Simultaneous color contrast.[11]

In Figure 4.1, all surface regions with red patches are physically the same, and analogously for green, blue and yellow. The phenomena can be described as follows: (i) the five red patches on the left look darker than the five red patches on the right, (ii) the five green patches on the left look darker than the five green patches on the right, (iii) the blue patches on the left look darker than the blue patches on the right, (iv) the yellow patches on the left look darker than the yellow patches on the right.

These phenomena are normally labelled as "simultaneous color contrast". As the term "simultaneous" suggests, the phenomena concern color contrasts in a synchronic sense.[12] In this case, surface regions with the same physical makeup and the same illumination conditions appear to have different colors. For instance, for the surface regions with red patches, given that there is no difference in physical makeup regarding the surface regions underlying these red patches, there should be no difference in the *physical* colors of these surface regions. However, there is indeed a difference in the *phenomenal* reds that visual experience represents

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[10] The copyright belongs to https://www.colorduels.com/what-is-simultaneous-contrast/.
[11] Simultaneous color contrast is more noticeable on a computer screen compared to printed paper. Thus, it is highly recommended to view the digital version of this picture.
[12] Simultaneous color contrasts are distinct from *successive* color contrasts in a diachronic sense.

these surface regions as having. Hence, there is a difference in the phenomenal reds without a difference in the physical reds. This is exactly a counter-example to the aforementioned supervenience thesis. Thus Premise 2 is true.

Hence, we can conclude that representationalism and the Color Thesis cannot both be true. They are mutually exclusive.

Before addressing the potential objections to my argument, there is still work to be done. So far, I have only displayed a case of simultaneous color contrast (Figure 4.1), which is adequate for the argument but not for the ongoing discussion. We still need a precise notion of simultaneous color contrast.

4.3 Simultaneous Color Contrast

The characterization of simultaneous color contrast is a subtle, little-discussed topic. There is no consensus among philosophers on what simultaneous color contrast is.[13] In this section, I will give a tentative definition.

Simultaneous color contrast (SCC) can be characterized as follows: in an environment populated with everyday objects under ordinary daylight conditions, when there are different colors presented adjacently in a certain arrangement to be visually perceived by an ordinary perceiver, a pair of contrasting colors is SCC if and only if the color contrast of the pair, when globally observed, is different from the color contrast of the pair when observed in isolation.

Formally, in an ordinary context *C*, for color shades S_1, S_2, S_3, … which are presented adjacently in visual experience *E* in a certain arrangement *A* to a perceiver *P*, the definition of SCC is:

$\mathrm{C_g}(S_{\mathrm{g}}x, S_{\mathrm{g}}y)$ is SCC iff $\mathrm{C_g}(S_{\mathrm{g}}x, S_{\mathrm{g}}y)$ is different from $\mathrm{C_i}(S_{\mathrm{i}}x, S_{\mathrm{i}}y)$.

Here, $\mathrm{C_g}(S_{\mathrm{g}}x, S_{\mathrm{g}}y)$ stands for a color contrast relation between shades $S_{\mathrm{g}}x$ and $S_{\mathrm{g}}y$, when *globally observed in context*, whereas $\mathrm{C_i}(S_{\mathrm{i}}x, S_{\mathrm{i}}y)$ stands for a color contrast relation between shades $S_{\mathrm{i}}x$ and $S_{\mathrm{i}}y$, when *observed in isolation*. $S_{\mathrm{g}}x$ and $S_{\mathrm{i}}x$ are shades of region *x* at two different times. $S_{\mathrm{g}}y$ and $S_{\mathrm{i}}y$ are shades of region *y* at two different times. "Observed in isolation" means that a color contrast effect is noticed by *P* when extra effort is made by *P* to

[13] To notice the subtlety of the topic, here are four different examples. Cohen (2009) classifies simultaneous color contrast as a case of intra-personal color variation. Allen (2016: Ch. 3) has a section titled "Intra-Personal Variation" in his monograph. But he remains silent about simultaneous color contrast in this section. Later in the book, Allen briefly characterizes it as "changes in an object's appearance that are not due to differences in the illumination" (2016: 112). Byrne and Hilbert (2003) regard simultaneous color contrast as a color illusion, which we will discuss in Section 4.4. Tye (2000) takes simultaneous color contrast to be an intentional inexistent, which we will discuss in Section 4.5.

particularly attend to the regions of the contrast. "Globally observed in context" means that a color contrast is noticed by P in context normally, without such extra effort.

According to this definition, Figure 4.1 is just a limiting case of SCC. In Figure 4.1, let $C_g(S_gx, S_gy)$ stands for the contrast between the leftmost and the rightmost blue shade. When globally observed, there is a contrast $C_g(S_gx, S_gy)$. However, when observed in isolation, there is no contrast between S_ix and S_iy at all.

Let us further assume that when there is no contrast between S_ix and S_iy, $C_i(S_ix, S_iy)$ is assigned the value zero, and when there is a contrast, $C_i(S_ix, S_iy)$ is assigned a positive number p proportional to the degree of color contrast. For a limiting case like Figure 4.1, $C_g(S_gx, S_gy) = p$ and $C_i(S_ix, S_iy) = 0$. Comparing $C_g(S_gx, S_gy)$ and $C_i(S_ix, S_iy)$ is not difficult. However, there is whole range of cases where $C_g(S_gx, S_gy) = p_1$ and $C_i(S_ix, S_iy) = p_2$ (with $p_1 \neq p_2 \neq 0$). These cases all fall under SCC. The problem is that, in these cases, comparing $C_g(S_gx, S_gy)$ and $C_i(S_ix, S_iy)$ is extremely difficult. This challenges us to better understand them, but it is not a reason to ignore them. To cover these general cases, it is instructive to discuss certain features of SCCs, The four features to be discussed are: ubiquity, predictability, intersubjective accessibility and coherence with other color phenomena.[14]

First, SCC is ubiquitous. That is given by the definition. When there are color contrasts adjacently presented in an ordinary environment under daylight conditions, SCC ubiquitously exists when there are observations. Specifically, the whole range of cases where $C_g(S_gx, S_gy) = p_1$ and $C_i(S_ix, S_iy) = p_2$ ($p_1 \neq p_2 \neq 0$) guarantee the ubiquity of the phenomenon.

There might be a doubt: If SCC is ubiquitous, why is it hard for us to notice it? This doubt can be eliminated by the following reasoning.

Sure, SCC is very hard for us to notice, but that does not entail that it isn't ubiquitous. To understand this, we must first examine the role of the *arrangement* of these colors in our observation. Ontologically, the arrangement of color shades in a context is irrelevant to the existence of SCC. Epistemologically, however, this arrangement is crucial for our *noticing* SCC and forming perceptual beliefs about it. This is clearly shown by Figure 4.1. As discussed, Figure 4.1 is a limiting case of SCC. The color strips in Figure 4.1 are deliberately arranged such that we can easily notice the color contrast. Let $C_g(S_gx, S_gy)$ stand for the color contrast between the leftmost blue and the rightmost blue shades when globally observed, and $C_i(S_ix, S_iy)$ stand for the contrast of the same regions when observed in isolation. The degree of contrast between S_ix and S_iy (when observed in isolation) is zero, because S_ix and S_iy are

[14] In the literature, the features of SCC are rarely discussed systematically. As far as I know, the feature most often mentioned is predictability. Goethe (1810) and Chevreul (1839) famously mention the law-like features of SCC.

deliberately arranged to be the same. This makes it easier for us to compare $C_g(S_g x, S_g y)$ and $C_i(S_i x, S_i y)$. The reason is that, in order to ensure a difference between $C_g(S_g x, S_g y)$ and $C_i(S_i x, S_i y)$, we only need to guarantee a contrast between $S_g x$ and $S_g y$. However, given the richness of color phenomena, this method does not work in an ordinary context, since the difference between $C_g(S_g x, S_g y)$ and $C_i(S_i x, S_i y)$ is usually too small to be noticed. That is, if $C_g(S_g x, S_g y) = p_1$ and $C_i(S_i x, S_i y) = p_2$ (with $p_1 \neq p_2 \neq 0$), it is hard to notice the contrast of the two regions x and y, and compare p_1 with p_2 based on vision alone. Hence, difficulty in noticing SCC does not mean that SCC is not ubiquitous.

Second, SCC is predictable in many cases. I will present a model that can predict many SCCs in an ordinary context. The model consists of empirically based law-like statements,[15] including, but are not limited to, the following:[16]

(a) Other things being equal, the same surface region with blue shades appears brighter adjacent to yellow shades than adjacent to other chromatic shades, such as red shades.

(b) Other things being equal, the same surface region with yellow shades appears brighter adjacent to blue shades than adjacent to other chromatic shades, such as red shades.

Two examples can help illustrate how these statements predict SCC.

The first example pertains to a prediction made by (a). Statement (a) predicts that the same surface region with blue shades in a yellow context appear brighter than in a red context. An example is Figure 4.2. In Figure 4.2, the blue shades in a yellow context on the right side appear brighter than the blue shades in a red context with the same underlying physical makeup on the left side.

[15] The model is open to further modifications by accounting for facts of physiology or brain science. Of course, one can also attempt to build a reductionist explanatory model that can make the same predictions. But any reductionist analysis is supposed to be compatible with empirical observation, too.

[16] Besides (a) and (b), we can go on to formulate law-like statements regarding green shades adjacent to red shades and non-red shades, respectively, red shades adjacent to green shades and non-green shades, respectively, grey shades adjacent to brighter grey shades and darker grey shades, etc. Attempts to formulate a law for color contrast phenomena may be traced back to Michel Eugène Chevreul's color theory in *The Principle of Harmony and Contrast of Colors* (1839).

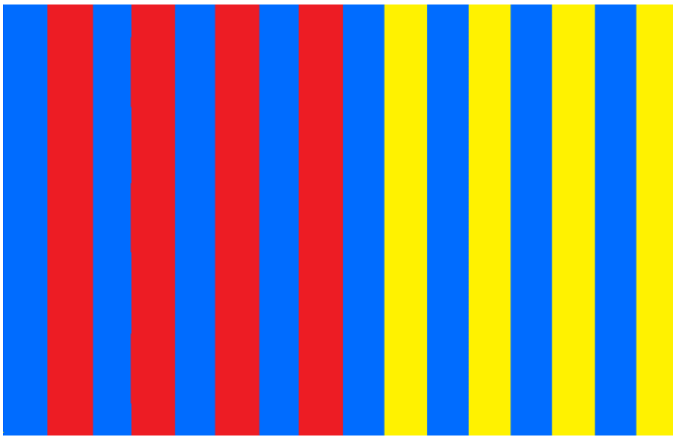

Figure 4.2: Blue shades.[17]

The second example pertains to a prediction made by (a) and (b). The combination of (a) and (b) predicts that, other things being equal, the contrast in brightness between surface regions with blue and yellow shades is maximized when these regions are adjacent. This effect has long been used by painters under the name "color juxtaposition" to create a stronger visual impact in a painting. The commonly used color juxtaposition pairs are red–green, blue–yellow, blue–orange, yellow–purple, etc. For instance, to generate a stronger visual impact by using the blue–yellow juxtaposition, Vincent van Gogh famously drew the night sky blue rather than black (see Figure 4.3).

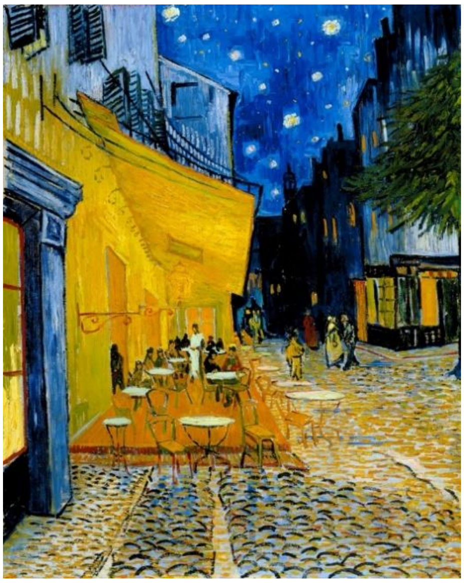

Figure 4.3: *The Café Terrace* by Vincent van Gogh.[18]

[17] It is highly recommended to view the digital version of this picture to perceive the more salient color effect.

[18] "Here you have a night picture without any black in it, done with nothing but beautiful blue and violet and green, and in these surroundings the lighted square acquires a pale sulphur and greenish citron-yellow colour. It amuses me enormously to paint the night right on the spot. They used to draw and paint the picture in the daytime after the rough sketch. But I find satisfaction in painting things immediately" (van Gogh, 1888).

The strong visual contrast between blue and yellow in van Gogh's painting is an example predicted by (a) and (b).

Third, SCC is intersubjectively accessible. This feature is obvious. Unlike the virtual colors of a hallucinated object, which can only be noticed by the hallucinating individual, SCC is intersubjectively accessible to all human beings with normal vision.

Fourth, SCC is coherent with other color phenomena. It is more basic than many other color phenomena. I will illustrate the point by comparing SCC with reflectance physicalists' color constancy,[19] which means that objects do not seem to change their colors when perceived under different illumination conditions, for example, ripe tomatoes seem to have the same red appearance under different illuminations. Here is why SCC is more basic than reflectance physicalists' color constancy. First, the latter relies on more elements in its characterization. It is characterized in terms of changes in illumination conditions, which, in contrast, is not necessary in characterizing SCC. Second, SCC is open to almost all metaphysical frameworks in the philosophy of mind, including eliminativist, reductionist and non-reductionist materialism, dualism, idealism and phenomenalism. In contrast, the reflectance physicalists' color constancy only works in reductionist and non-reductionist materialism, because it assumes the metaphysical distinction between the object and its illumination conditions, which requires color constancy to be characterized by how objects appear colorwise under different illumination conditions. This is highly restrictive. As for SCC, it concerns only color contrast and remains neutral on the nature of perceptually presented objects, making it compatible with any metaphysical view of them. Third, as will become clear in Section 7.4, reflectance physicalists' color constancy focuses only on the diachronic sense of color constancy, whereas the synchronic sense is completely undiscussed. In contrast, SCC is primarily about synchronic color contrast. Given that it is plausible to assume that the diachronic sense of a color phenomenon is built up from its synchronic sense at different times, SCC is more basic than reflectance physicalists' color constancy.

To summarize, I define SCC and list its four features in this section. The rest of this chapter will discuss two reflectance physicalists' objections to the argument from mutual exclusiveness. In Section 4.4, I will address Byrne and Hilbert's objection that SCC can be dismissed because it is a color illusion. In Section 4.5, I will defend against Tye's objection that SCC can be sidelined because it is an intentional inexistent.

[19] In Section 7.4, we will discuss the inadequacy of reflectance physicalists' version of color constancy. Here, we neglect the problem and work with the presupposition that their version is adequate.

4.4 Simultaneous Color Contrast as an Illusion?

As discussed in Section 4.2, reflectance physicalists must agree with Premise 1. The only way out for reflectance physicalists is to reject Premise 2. One straightforward way of rejecting Premise 2 would be by claiming that SCC is an exception which can be safely dismissed. This is exactly what they do. In this section, I will focus on Byrne and Hilbert's objection.

In order to dismiss SCC, Byrne and Hilbert point out the oddity of perceptual theories that are built upon color illusions such as SCC. The following paragraph is the only place where Byrne and Hilbert (2003) mention their reasoning:

> First, do objects like tomatoes, strawberries, and radishes really have the distinctive property that they appear to have? Second, what is this property? … It is important to emphasize that a negative answer to the first question is a genuine theoretical option. … a visual illusion is precisely a case where an object visually appears to have a property it does not in fact have. … There are also color illusions, for instance produced by changes in illuminants, or by simultaneous contrast. An example of the latter kind of color illusion is neon color spreading, in which a region that is in fact white appears pink (Nakayama et al. 1990; Van Tuijl & de Weert 1979). A negative answer to the first question amounts to the view that color illusions are the rule, not the exception. This might seem odd, but it is not incoherent. (2003: 4)[20]

[20]Neon color spreading cannot be classified as a clear-cut case of SCC mentioned above. In contrast to Figure 4.1, which is a paradigmatic case of SCC, Figure 4.4 shows that neon color spreading is phenomenologically complicated. While it appears that there is a circular region of bright blue, a close examination tells us that there is no such region, and that all surface regions demarcated by lines seems to have the same whiteness. In Byrne and Hilbert's notion of neon color spreading, at least three factors must be carefully distinguished: (1) the cognitive influences on how a circle is perceived, (2) the perception of lines in both a local and a global sense, and (3) the perception of different-colored lines that seems to play salient roles in generating the overall perceptual impression than the simple SCC between white, black and blue. Thus, neon color spreading is more complicated than SCC. It is not a proper case of SCC.

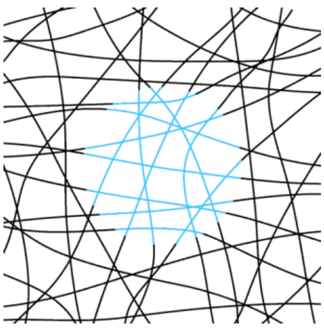

Figure 4.4: An example of the neon color spreading phenomenon.

Byrne and Hilbert classify SCC as a color illusion in the sense that it amounts to a case "where an object visually appears to have a property it does not in fact have". Moreover, they agree that it is not incoherent to claim that SCCs are the rule, but still maintain that not treating them as exceptions is odd. Accordingly, SCCs can be set aside as exceptions.

The above reasoning is open to various rejections and challenges. Here, I mention three. To state it clearly, my aim is not to propose an illusion-based color theory. That would be a topic worthy of an independent treatment.[21]

First, according to the discussions in Section 4.3, it is impossible to set aside SCCs as exceptions. Section 4.3 concludes that SCCs are perfectly normal, which are not illusions but just hard to be noticed. SCCs have features of ubiquity, predictability, intersubjective accessibility and coherence with other color phenomena, making them impossible to be treated as exceptions. Moreover, given that SCC is more basic than reflectance physicalists' color constancy (see Section 4.3), it is not reasonable for reflectance physicalists to set aside SCCs as exceptions.

Second, to reject a theoretical option due to its counterintuitiveness does not sound like a reasonable choice. It is quite common that what seems odd to some philosophers appears obvious to others. Thus, an appeal to counterintuitiveness is not a good reason. Trying to understand oddities is a key source of theory development in any domain. Color scientists, by contrast, deem SCC to be a significant explanandum. In color science, color appearance models are the most commonly used models, which is motivated exactly by the theoretical need to account for phenomena like SCC.[22]

Third, one background assumptions underlying Byrne and Hilbert's reasoning is that their notion of color illusion relies on their notion of veridical color perception. In this dissertation, I too work with the hypothesis that the notion of veridical color perception is meaningful. However, there is no a priori reason to assume this, and the notion might be empty. An independent discussion is required.

So much for Byrne and Hilbert's response. Now, we will move on to Tye's objection.

4.5 Simultaneous Color Contrast Grounded in Intentional Inexistents?

Tye has a more specific reason for setting aside SCC as an exception. He writes:

[21] For an illusion-based theory of color, see Mackie 1976, Boghossian and Velleman 1989 and possibly Chalmers 2006.

[22] See Fairchild 2013. In Chapter 6 of the book, Fairchild lists SCC as the *first* kind of phenomenon required to be accounted for by a color appearance model.

> [T]he colors things are experienced as having as a result of the contrast between the real color of the stimulus and the real color of the background are merely apparent. They do not really exist. Our experiences represent them as being instantiated when in reality they are not. Such colors on such occasions are mere intentional inexistents. That simultaneous color contrast, understood in this way, is produced by, and explicable in terms of, the workings of the visual system (e.g., by opponent processing) is something no color realist need deny. (2000: 156)

The upshot of Tye's view is that the colors in SCC can be treated as intentional inexistents produced by the visual system, alleged to be compatible with reflectance physicalism. Is this a successful response? More specifically, is Tye's view adequate to sideline SCC as an exception such that Premise 2 that it is not the case that phenomenal colors supervene on physical colors (because the supervenience relation is falsified by SCC) can be rejected?

To clarify upfront, even if one ignores the controversies about the notion of intentional inexistence, there is a decisive reason to refute Tye's view: given the discussed features of SCC, it is impossible for any color theorists to set it aside as an exception. Yet, this is not a direct response. Admittedly, there an initial plausibility of treating colors in SCC as intentional inexistents. In what follows, I will show that, despite the initial plausibility of Tye's view as a refutation of Premise 2, a further examination will show that, ultimately, Tye's view indirectly substantiates Premise 2. As a result, colors in SCC are neither physical colors nor intentional inexistents, rather they are still physical aspects of the environment in a special sense! Tye's view poses no challenge to Premise 2.

Tye's view is a rejection of Premise 2 for the following reason: Colors in SCC are metaphysically irrelevant to the external environment and exist only as intentional inexistents produced by, *and only by*, the visual system. In Premise 2, phenomenal colors, as represented colors, are real aspects of the environment. Thus, it is incorrect to assume that colors in SCC are phenomenal colors as discussed in Section 4.2, because colors in SCC are not real aspects of the environment at all. It follows that SCC pose no challenge to the supervenience of phenomenal colors on physical colors. SCC cannot be used to support Premise 2.

I will discuss two problems with this response.

First, this response assumes a clear-cut metaphysical distinction between real colors and colors as intentional inexistents. More precisely, situate it within reflectance physicalism, for whatever color phenomenon, *all* perceptually presented colors are produced by the visual system. In veridical cases, the presented colors are real (represented) colors. In non-veridical cases such as SCC, the presented colors in SCC are intentional inexistents. If the distinction between the real colors and colors as intentional inexistents can somehow be reflected in color experience, this brings us to a question: What are the conditions for recognizing whether a color experience is veridical or non-veridical? If there is no way for us to recognize veridical (or non-veridical) color experiences as such, then we have a strong reason to assume that the above distinction is metaphysically invalid (or conceptually void) and cannot be used to explain SCC.

As a common reply, reflectance physicalists can appeal to the notion of standard conditions, according to which there are standard illumination conditions under which standard perceivers can represent physical colors veridically in their color experiences. Almost all forms of monist color objectivism, including reflectance physicalism, rely on the existence of standard conditions.[23] Despite doubts, I assume their existence in the current discussion.[24] That is, I stipulate that if one can distinguish between standard and non-standard conditions, then one can distinguish between real and unreal colors. For instance, assuming standard conditions, such as a certain kind of daylight, we can then successfully ascertain the real whiteness of a wall under midday sunlight and note as unreal the canary yellowness seemingly instantiated by the same wall during the sunset.

Although intuitive, this reply does not work for SCC, since SCC can occur under both standard and non-standard conditions. As clearly shown by Figures 4.1 and 4.2, the colors in SCC are observable under both standard and non-standard conditions. The crux is that illumination conditions do not play an essential role in discovering colors in SCC as real or unreal. Thus, the appeal to the notion of standard conditions fails.[25] One cannot reject Premise 2 by reasoning as follows: Given that the supervenience of phenomenal colors on physical colors holds *only* under standard conditions, where color experiences are veridical, the colors in SCC pose no challenge to this supervenience relation because they are found non-veridical under non-standard conditions.

Now I discuss the second problem, which arise from a follow-up question to Tye's view and ultimately reveals that Tye's view can indirectly substantiates Premise 2.

The follow-up question is: If colors in SCC as intentional inexistents are metaphysically irrelevant to the environment, how can one account for the phenomenal differences between these colors?

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[23]See Byrne and Hilbert 2003.

[24]Hardin (1988) and Cohen (2009) argue that it is doubtful whether there can be non-stipulative settings of standard conditions for the alleged veridical color perception.

[25] Instead, it can be foreseen that SCC can be used to debunk the distinction between standard and non-standard conditions.

On Tye's view, the answer must be that colors in SCC supervene on certain properties of the visual system in the sense that there is no difference in the former without a difference in the latter. The question must be answered thus since Tye explicitly says that these colors are produced by the workings of the visual system. If we add this answer to the reflectance physicalists' view that colors in SCC do *not* supervene on physical colors, then there is a key thesis:

> Colors in a case of SCC, call them Colors_s, supervene on the color-related properties of the visual system, Colors_v. Colors_v do not further supervene on the physical colors, Colors_p, in the environment, *E*.

Although this thesis states that Colors_v do not supervene on Colors_p, it does not address whether Colors_v supervene on *E* more globally by involving factors over and above Colors_p. As will become clear, an analysis of the relation between Colors_v and *E* will reveal the indirect way in which Tye's view substantiates Premise 2.

Within the context allowed by reflectance physicalism, there are four theoretical options for exhaustively understanding the relation between Colors_v and *E*, based on the four possible combinations of a dysfunctional or normally functioning visual system and the visual system' dependence or independence from E:[26, 27]

The first option: Colors_s are the outcome of a *dysfunctional* visual system where the system's functioning is independent of *E*, and Colors_v do not supervene on *E*.

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[26] To account for the supervenience relation between Colors_s and Colors_v, reflectance physicalists need to answer whether Colors_s are outcomes of a dysfunctional or of a normally functioning visual system. This is clear in the in the previous quotation of Tye. For Byrne and Hilbert' view, see the vision science premise in Section 2.2: "[W]e need a property that human visual systems could plausibly recover from the responses of the three kinds of cone photoreceptors" (2003: 9). In contrast, Chalmers, who is not a color physicalist, might claim that colors in SCC are Edenic colors that exist in an Edenic world as a metaphysically possible world, and that there is no need to appeal to visual systems at all. Chalmers (2006) does not mention SCC in his paper on color. But I am pretty sure that he would answer the question in this way.

[27] To account for relations between Colors_v and *E*, reflectance physicalist needs to answer whether there are ontological dependence relations between visual systems (instantiating Colors_v) and *E*. This is directly shown in the causal premise in Section 2.2, according to which causation as an ontological dependence relation is fundamental. By contrast, Chalmers, who is not a color physicalist, claims that the causal process assumed by color physicalists is not fundamental because the causal process that leads to color experiences in this world only mirrors the bringing about of color experiences in the Edenic world, which is a metaphysically possible world. Thus, he writes, "If an experience is such that its perfect veridicality conditions require the instantiation of primitive property *X*, then the experience's imperfect veridicality conditions will require the instantiation of a property that matches *X*. As before, a property matches *X* (roughly) if it plays the role that *X* plays in Eden. The key role is causing experiences of the appropriate phenomenal type. In our world, these properties will typically be physical properties: the imperfect counterparts of *X* (2006: 72).

The second option: $Colors_s$ are the outcome of a *normally* functioning visual system where the system's functioning is independent of *E*, and $Colors_v$ do not supervene on *E*.

The third option: $Colors_s$ are the outcome of a *dysfunctional* visual system where the system's functioning depends on *E*, and $Colors_v$ supervene on *E* in a more global sense.

The fourth option: $Colors_s$ are the outcome of a *normally* functioning visual system where the system's functioning depends on *E*, and $Colors_v$ supervene on *E* in a more global sense.

All four options need to be examined. It seems that Tye's view favors the first option. If the first option is correct, it is more plausible that $Colors_s$ are intentional inexistents. As will become clear, the first option fails. Here, what interests us are the third and the fourth options, which entails that:

> If the third or the fourth option is correct, then $Colors_s$ are physical in the sense of supervening on *E* more globally by involving factors over and above the local $Colors_p$ (as assumed by reflectance physicalists).

This claim is significant because, if the antecedent can be established, it follows that $Colors_s$ are neither intentional inexistents nor physical colors, but still something physical in *E*.

I will argue that the antecedent can be established and that Premise 2 still holds. Given that the above four options exhaust all possibilities regarding the relation between $Colors_v$ and *E*, in the following, I only need argue that the first and the second options can be rejected within the context allowed by reflectance physicalism. The first and the second options shares a common thesis that, in cases such as SCC, the working of the visual system is independent of *E*. I will reject this common thesis with two counterarguments.

The first counterargument is that the four features of SCC make it impossible to accept this common thesis. Each of the four features – ubiquity, predictability, intersubjective accessibility and coherence with other color phenomena – can be developed into a related objection. Here, I prioritize predictability, since it makes the rejection more obvious. Recall that the law-like claim (a) predicts that the same surface region with blue shades appear brighter when adjacent to surface regions with yellow shades than when adjacent to surface regions with red shades. This clearly shows that a certain arrangement of surface regions, which is a feature of the external environment, corresponds to the occurrence of a certain SCC. For a physicalist who is supposed to endorse the thesis of causal closure of the physical world, it is natural to assume that a certain SCC ontologically depends on a certain arrangement of physical surfaces.[28] This claim is consistent with the causal premise of reflectance physicalism. Hence, it is clear that a reflectance physicalist must agree that, for SCC, the visual system's functioning ontologically depends on *E*, which conflicts with the above common thesis. The first counterargument is thus well-founded.

The second counterargument is that reflectance physicalists' view of perception (see below), with a slight modification consistent with a physicalist view of perception, conflicts with the above common thesis.

According to reflectance physicalists' view of perception, in the veridical case, for a subject *S* in certain mental states, to experientially represent, say, red is just for *S* to be in a certain brain state that functionally detects the red reflectance property.[29] The same view can be generalized to arbitrary other colors (except blackness).[30] Here, the notion of detection is best understood via an analogy. Just like a thermometer detects the temperature in the environment and represents it by means of units of the measurement such as centigrade, *S*'s brain (equipped with a visual system) detects the red reflectance property in the environment and *S* experientially represents red as certain qualitative features.

For a physicalist, it is quite plausible that the visual system detects features of the environment, and that, further, this detecting is detecting in a somewhat global sense, rather than in the local sense of pointwise correspondence. "Somewhat global" means that what is detected by the visual system involves factors in the environment over and above SSRs or other physical colors. For instance, a visual system might detect SSRs just indirectly and partially by means of detecting a certain kind of spatial arrangement of physical surfaces. This modified view is consistent with a physicalist view of perception, but slightly distinct from the reflectance physicalists' view of perception. The latter assumes that the visual system detects SSRs directly. That is, it assumes that the visual system indirectly detects a certain kind of spatial arrangement of physical surfaces by means of directly detecting SSRs. To illustrate the point, Figure 4.5 an example where blue stripes are arranged adjacent to red and yellow stripes. According to the modified view, one's visual systems indirectly detects the

[28] When I say that a physicalist is supposed to underwrite the causal closure of the physical world, I mean physicalists since the second half on the 20th century. See Papineau 2001 for a discussion of physicalism that is based on the causal closure thesis.
[29] By "color physicalists' general view of perception" I mean reductionist externalist representationalism, which is different from externalist representationalism simpliciter because the former view further identifies perceptual representation with a detection relation between brain states and the environment. This view is defended by Michael Tye (1995, 2000). Byrne and Hilbert (2003) also make the analogy between a thermostat's function of detecting the temperature and the visual experience of physical colors.
[30] See Chapter 6, where I will argue that color physicalism cannot account for blackness counting as a color.

SSRs of this visual scene partially by means of detecting the horizontal spatial arrangement on the physical surface. The arrangement is "horizontal" relative to a perceiver, whose direction is represented by the black arrows.

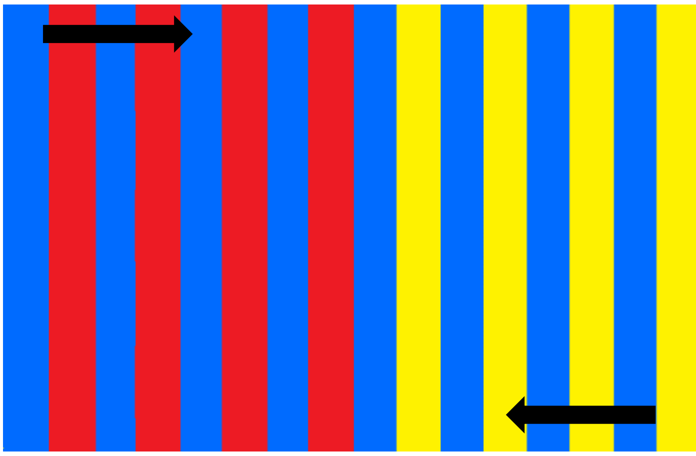

Figure 4.5: A spatial arrangement of colored stripes.

The modified view has some advantages in accounting for SCC. On this view, $Colors_s$ supervene on kinds of spatial arrangement on physical surfaces, in the sense that there is no difference in $Colors_s$ without a difference in the kinds of arrangement. In Figure 4.5, the difference between the right-hand-side blue and the left-hand-side blue supervenes on the difference in the horizonal arrangement of the physical surface.

Note that the modified view is far from being a mature theory. It is the physicalists' turn to evaluate and substantiate this reasoning. For my current purposes, all I need is just the notion of detection in a global sense: what a visual system detects involves factors over and above SSRs or other physical colors. That is, whatever might be detected by a visual system, it is not just SSRs or other physical colors. The above analysis has demonstrated this point. Thus, the second counterargument is valid.

So far, I have presented two counterarguments against the first and the second options. Since the four options exhaust the possibilities, we can conclude that, in the context allowed by reflectance physicalism, either the third or the fourth option must be correct. Combining this with the previously formulated claim: If the third or the fourth option is correct, then $Colors_s$ are physical in the sense of supervening on *E* more globally by involving factors over and above the local $Colors_p$ (as assumed by reflectance physicalists). We can conclude that colors in SCC are physical rather than intentional inexistents. Thus, Tye's view poses no challenge. Accordingly, Premise 2 still stands. It follows that representationalism and the Color Thesis cannot both be true. They are mutually exclusive.

5

Perceptual Indeterminacy

This chapter examines the premise from representationalism of the Color Thesis. Recall the premise: “[C]olor vision of human beings and many other organisms exhibits approximate color constancy, … for instance, tomatoes do not seem to change color when they are taken from a sunny vegetable patch into a kitchen illuminated with incandescent light. Assuming that our perceptions of color are usually veridical, we therefore need a physical property of objects that is largely illumination-independent – a physical property that an object can retain through changes in illumination” (2003: 9). As discussed, the premise is based on two points. The first is color constancy: despite varying illumination conditions, an object seems to have a stable (or constant) color appearance. The second is representationalism: in a good case, a color experience veridically represents the surfaces of objects as being colored in such-and-such a way. Given these two points, reflectance physicalists conclude that represented colors are *illumination-independent*.

The literature identifies many issues with this premise. Three major problems are commonly discussed.

The first problem is the unwarranted emphasis on color constancy as the main explanandum for a color theory. Color phenomena are very rich. For instance, color variance is ubiquitous: under the same illumination, the same monochrome surface of an object exhibits different color appearances to the same perceiver, or to different perceivers, or to perceivers from different species, as presented in Section 1.1. Given the ubiquity of color variance at the intrapersonal, the interpersonal and the inter-species level, how is it possible that color constancy can be considered as the main explanandum for a color theory? There seems to be no *a priori* reason for casting aside color variance and only considering color constancy as the main explanandum.

The second problem is the unwarranted emphasis on the constancy aspect of color constancy. Color constancy has both constancy and variance aspects. Both are intrinsic to color constancy and interdependent. However, Byrne and Hilbert’s characterization that “tomatoes do not seem to change color when they are taken from a sunny vegetable patch into a kitchen illuminated with incandescent light” only emphasizes the constancy aspect (insofar as tomatoes exhibit a constant color appearance under different illuminations) without mentioning the variance aspect (insofar as tomatoes exhibit slightly *different* color appearances under these illuminations). A sufficient characterization of color constancy cannot mention one aspect without mentioning the other. The above characterization is inadequate. Hence, the premise of representationalism is inadequate. Color constancy is a key element not only of reflectance physicalism but of all main versions of reflectance-grounded objectivism. Given the overlap, I will set the topic aside for the moment and reconsider it in Chapter 7 when discussing reflectance-grounded objectivism in general.

The third problem is that of representationalism. Note that the debate surrounding representationalism belongs to the philosophy of perception, where color *perception*, rather than color itself, is the central subject matter. [1] There are many arguments against representationalism: the structure mismatch argument, the conceived "altered spectrum" thought experiment and the internal dependence argument.[2] These arguments, along with the related exchanges between different philosophers, are interesting and merit independent examination. However, they primarily target representationalism rather than reflectance physicalism. Specifically, they do not touch upon the color phenomenology of representationalism, which is crucial for reflectance physicalism. This certainly weakens their force as arguments against reflectance physicalism. For this reason, I will not delve into them. In this chapter, instead, I focus on the type of argument that concerns the reflectance physicalists' appeal to representationalism. In particular, I address the problem arising from color phenomenology: the indeterminacy of representational content under representationalism. Roughly put, representationalism is false because its color phenomenology cannot guarantee the determinacy of representational content.

In the literature, the indeterminacy of representational content is not an often-mentioned point, but its significance is noticed by some philosophers, such as Travis (2004) and Chalmers (2006). Both Travis' and Chalmer's arguments suggest that, for a given visual scene, the determinacy of the representational content cannot be guaranteed by the color

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[1] Strictly speaking, there is no clear-cut distinction between the philosophy of color and the philosophy of color perception: for color objectivists, the debate on representationalism belongs to the philosophy of color perception; for color subjectivists, the debate belongs to the philosophy of color.

[2] The structure mismatch argument claims that there is a "mismatch between resemblances among the apparent colours of objects and the resemblances among those objects' reflectance" (Pautz 2021: 371), for instance, reflectances of purple, blue and green objects do not show resemblances between purple and blue and green. The conceived "altered spectrum" thought experiment is that imagine two people looking at the same object, for instance, a red tomato, they might have altered color experiences without knowing it (say, with one having red experience and the other having greed experience), but they both correctly represent the tomato as being red. This suggests that the phenomenal character of experience is not accounted for by representational content, which conflicts with externalist representationalism. Besides, Block (2003) also discusses actual cases of altered spectra. The internal dependence argument relies on the observation that "decades of research in psychophysics and neuroscience support the idea that, even in *normal experience*, the explanation of why you experience one sensible property rather than another resides in the nature of your internal neural state, not the external physical property detected" (Pautz 2021:152; italics in the original). This conflicts with externalist representationalism.

phenomenology of the scene, because the color phenomenology is undetermined. Arguably, this entails the falsity of representationalism.

As will become clear, my argument against representationalism shares the same conclusion with Travis' and Chalmer's arguments that the determinacy of representational content cannot be guaranteed by color phenomenology. However, I further add that whether the color phenomenology of a scene is determinate depends on whether it is treated as basic. I will argue that the color phenomenology of a scene is determinate if it is treated as basic, but this is still insufficient to guarantee the determinacy of representational content. This shows that representationalism is false. Along the way, I will scrutinize the subtle relationships between color phenomenology and representational content.

The chapter is structured as follows: Section 5.1 investigates the nature of color phenomenology by focusing on shadows, which establishes the basic color phenomenology of a scene and provides the foundation for the following discussion. Section 5.2 presents the argument from content indeterminacy against representationalism. Section 5.3 focuses on one important response from reflectance physicalists that appeals to a widespread conception of color phenomenology among philosophers. Specifically, one assumption of this color phenomenology is highlighted, namely that the color–illumination distinction is perceptually given. In Section 5.4, I will reject this assumption based on a discussion of the spatial dimensionality of color experience. The argument against the color–illumination distinction will be presented. In Section 5.5, I respond to an objection to this argument by probing into the imaginary nature of visual depth.

5.1 The Phenomenology of Shadows

This section investigates the nature of color phenomenology by discussing the case of shadows and argues for a fundamental approach to color phenomenology, which results in the basic version of the color phenomenology of a given scene.

To do color phenomenology means to have a certain way of characterizing color phenomena. One difficulty in understanding how to do color phenomenology is how to take into account one's beliefs (one's background beliefs, perceptually suggested beliefs, or one's color theories) about colors when characterizing color phenomena. It is quite common that these beliefs guide one's characterization of a color phenomenon. For instance, due to their differing beliefs, philosophers characterize the same color phenomenon quite differently.[3] It

[3] In Section 7.4, there are cases where different philosophers characterize color constancy differently. It can be inferred that the difference is due to their held beliefs.

is then natural to ask: is there a *fundamental* approach of doing color phenomenology which results in the *basic* color phenomenology of a scene? I will argue that the answer is yes.

We focus on the case of shadows. As an example, Figure 5.1 is a photo of a white wall on which there is a shadow cast by some leaves. Imagine that you have a visual experience like this. What is its color phenomenology?

Figure 5.1: The case of shadows.

At first glance, intuitively, two versions of color phenomenology are plausible. The first version is initially characterized as:

Version A: The wall appears to have two colors, white and gray.

Version A suggests that the two colors the wall appears to have are inherited from two distinct phenomenal colors presented in the color experience, with no additional colors over and above these two. Importantly, Version A does not factor in illumination conditions, motivated by the idea that color phenomenology is not informative about them. While it may seem natural for one to hold a belief about the existence of certain illumination conditions in an environment (due to either one's background beliefs, or one's perceptually suggested beliefs, or one's metaphysical assumption that, in good cases, one's visual system is informative about illumination conditions), that belief is set aside when doing color phenomenology. Actually, one can further modify Version A to make the color phenomenology less informative regarding object: there are two colors, whiteness and grayness, as of a visual object or nothing.[4] Call this Version A*. Version A* is of great importance. It denies the assumption

[4] "Visual object" implies that the sense of objecthood is given by a visual experience without the ontological commitment that there really is an object that is visually presented. Put another way, in no way does this color phenomenology suggests a perception-independent object.

that the only way to make sense of color phenomenology is to interpret it in terms of ways objects look in color aspects. Yet, for simplicity, I will work with Version A for now, and use Version A* when necessary.[5]

The second version is:

Version B: The wall appears to have the same underlying whiteness, despite a phenomenal difference between the unshadowed regions with phenomenal whiteness under the direct light and the shadowed regions with phenomenal grayness under the blocked light.

Version B is more informative about illumination by addressing two different illumination conditions. It is also more detailed about the wall's color properties by factoring in the "apparent sameness" of the differently illuminated regions of the wall. The motivation of Version B is that color phenomenology should be more informative about the environment. Specifically, it results when one lets one's beliefs about illumination conditions inform one's characterization of the color phenomenon.

Version B implicitly assumes that one's beliefs about illumination conditions are correct. However, this assumption is ad hoc for this case, as one's beliefs might well turn out to be incorrect. To illustrate the point, consider

The Case of Painted "Shadows": The visual scene like what is represented by Figure 5.1, realized by painting a wall in two colors and illuminating the wall uniformly (there is no shadow!). The painted wall looks indistinguishable to what is represented by Figure 5.1, to the extent that no clue whatsoever tells one whether the wall is shadowed or painted.

In this case, the visual scene provides no adequate information about the illumination. Based merely on the information given in the visual scene, one cannot guarantee the correctness of one's beliefs about illumination conditions when doing color phenomenology. Given the phenomenal indistinguishability of shadows and painted "shadows", how should one do the color phenomenology of shadows?

Here, what needs to be considered is that one can consciously hold the second-order belief that one's first-order belief about the illumination might be incorrect, due to the possibility of

[5] For instance, in the case of blackness, the method of Version A* is more useful than that of Version A. In the case of a blackness like that of vantablack, which absorbs almost all visible light, the color phenomenology is that there appears to be a quasi-two-dimensional black patch as of no object, which doesn't suggest any object at all. This can be well captured by the method of Version A*.

painted “shadows”. Accordingly, when doing the color phenomenology of shadows, one might be guided by this second-order belief to add another color phenomenology as the third plausible candidate:

> *Version C:* The wall appears to have whiteness in some regions and grayness in other regions under one *uniform* illumination.

Version C still includes illumination conditions. Specifically, what is added is the condition of uniform illumination, unlike in Version B where both blocked and direct light were included. To be mentioned, if one is not cautious enough that one’s beliefs might be incorrect due to the possibility of painted “shadows”, then it is highly possible that one retains the belief that the visual scene is produced by shadowing rather than painting. As a result, one’s phenomenology is still Version B.

Note that the sequence order of the two cases is arbitrary: had we started with the case of merely painted “shadows” we would, by the same analysis, still have the same three plausible candidates.

At this point, we can consider whether Version A, B or C is the appropriate color phenomenology in the case of shadows and come back to the question whether there is a fundamental approach of doing color phenomenology that delivers the basic color phenomenology of a scene.

For the case of shadows or the case of painted “shadows”, there are three candidate color phenomenologies. However, these three versions are not equally plausible. Despite the plausibility of Versions B and C, there is a clear sense that Version A is superior: it is immune to the possible incorrectness of one’s beliefs about illumination, while Versions B and C are not. Specifically, Version A can accommodate two different cases equally well. Meanwhile, Version B cannot accommodate the case of painted “shadows” with the same ease as it accommodates the case of shadows, because in the former case one’s beliefs about the illumination would be incorrect. Similarly, Version C cannot accommodate the case of genuine shadows with the same ease as it accommodates the case of painted “shadows”, because in the former case one’s beliefs about the illumination would again be incorrect.

In conclusion, Version A is the *basic* color phenomenology of the case of shadows and the case of painted “shadows”. The fundamental approach of doing color phenomenology is to detach it from any first-order beliefs about the illumination of a scene and only employ the concepts of color and object and phenomenological terms like “appears”, “seems to be”, “looks to be”, etc.[6]

The verdict that Version A is favored is well supported by scientific findings regarding the relation between light and perceived color (or “phenomenal color”, in philosophers’ terms). The scientific finding is that “*Any three differently colored lights whatsoever* can always be mixed in the correct proportion to produce *any color whatsoever*” (Feynman 2013/1963: Vol. I, Ch. 35; italics in the original). For instance, when properly mixing them, red, green and blue light can produce arbitrary colors. In this manner even arbitrary shades of gray can be produced. The same (or a phenomenally indistinguishable) shade of gray can be produced by appropriate red–green–blue illumination conditions. These can be realized by using different projector lamps and filters.[7]

This finding has great implications for color phenomenology. We can easily conceive the following case, which is practically realizable:

> *The Case of the Projected “Shadows”*: The visual scene like what is represented by Figure 5.1, realized by using different projector lamps and filters in a certain way (There is no shadow or paint!). The projected “shadows” is indistinguishable from the scene represented by Figure 5.1 to the extent that there is no clue to tell us whether the wall is shadowed, painted or illuminated by projectors.

In this case, the visual scene provides no adequate information about its illumination. Moreover, given that infinitely many different illumination conditions (realized by corresponding projector lamps and filters) can create the same visual scene, some exotic cases are realizable. Here is an example:

[6] Note that the object concept does not entail the ontological proposition that the characterized object is perception-independent. Version A*makes this clear.

[7] Here is a detailed illustration of how it can be realized from Feynman. “To illustrate the possibilities, we may use a series of four projector lamps which have filters on them, and whose brightnesses are continuously adjustable over a wide range: one has a red filter and makes a spot of red light on the screen, the next one has a green filter and makes a green spot, the third one has a blue filter, and the fourth one is a white circle with a black spot in the middle of it. Now if we turn on some red light, and next to it put some green, we see that in the area of overlap it produces a sensation which is not what we call reddish green, but a new color, yellow in this particular case. By changing the proportions of the red and the green, we can go through various shades of orange and so forth. If we have set it for a certain yellow, we can also obtain that same yellow, not by mixing these two colors but by mixing some other ones, perhaps a yellow filter with white light, or something like that, to get the same sensation. In other words, it is possible to make various colors in more than one way by mixing the lights from various filters” (2013/1963: Vol. I, Ch. 35).

The Exotic Case of the Projected "Shadows": A visual scene like what is represented by Figure 5.1, realized by one of the infinitely many ways of dividing the visual scene into smaller regions in which each particular region is ruled by one of the infinitely many possible illumination conditions under which the visual appearance of that region is the same as in the case of ordinary shadows.

Given the phenomenal indistinguishability of shadows, painted "shadows", and projected "shadows", how should one do color phenomenology?

Here, we should remind ourselves that one can deliberately hold the second-order belief that one's first-order belief about the illumination might be incorrect due the possibility of the (exotic) case of projected "shadows". Accordingly, when describing the color phenomenology of the case of shadows, one might let one's color phenomenology be guided by this second-order belief and add another version of phenomenology as the fourth plausible candidate. To use the exotic case of the projected "shadows" as an example:

Version D: The wall appears to have whiteness and grayness under certain projectively created illumination conditions. This overall impression results from how different regions look under the related local illumination conditions, where "local illumination conditions" mean a specific mixture of projectively created lights in each region.

Version D still includes the illumination conditions. Specifically, what is factored in are the projectively created illumination conditions, unlike the blocked and direct light in Version B or one uniform illumination condition in Version C. Note that if one is not sensitive enough about the possible incorrectness of one's beliefs due to the possibility of projected "shadows", then it is highly possible that one still holds the belief that the visual scene is produced by shadowing or painting. As a result, one's phenomenology might still be Version B or C.

Now we are in an even better position to strengthen the previous verdict that Version A is preferable.

For the case of shadows, or of painted "shadows", or of the projected "shadows", there are four plausible versions of color phenomenology, Versions A, B, C and D.[8] However, these four versions cannot hold with the same strength. Despite the plausibility of Versions B, C and D, there is a clear sense in which Version A is preferable: it is immune to the possible

[8] Note that the sequence order of these cases is arbitrary: had we started with the case of projected "shadows" we would, by the same analysis, have the same four plausible candidates.

incorrectness of one's beliefs about the illumination, while Versions B, C and D are not. Moreover, Version A is not just immune to the incorrectness one's beliefs about illumination, it is also immune to one's beliefs about illumination. In comparison, the other versions substantially rely on such beliefs. As long as one's color phenomenology is guided by one's beliefs about illumination, it fails if these beliefs turn out to be incorrect. Furthermore, the advantage of Version A is more obvious if we consider that the same visual impression can be generated under infinitely many different illumination conditions. The most extreme reasoning might be as follows: For a given scene, where there are no visual clues about illumination conditions, if one is sensitive enough to consider that the same visual impression can be generated under infinitely many different illumination conditions, and if we assume that each belief regarding the illumination conditions of the scene is equally probable to be correct, then the probability for a belief to be correct is zero.[9] In view of this, it is almost a truism that any color phenomenology guided by one's beliefs about illumination conditions fails. Therefore, although each version has its own plausibility, Version A is clearly preferable.

It is clear that Version A is the favored phenomenology, but in what sense is it the *basic* phenomenology?

Version A stands independently without needing to be interpreted through other versions, while the other versions all depend on some interpretation of Version A in the sense that *a certain color* in Version A is interpreted as *a shadowed*, *painted*, *standard-illuminated*, *non-standard-illuminated* or *projected color of a region* in other versions. For instance, Version B relies on an interpretation of Version A in the sense that "the same underlying whiteness" in Version B certainly does not result from what is phenomenally presented, namely the white and gray patches which figure in Version A, but from some further interpretation of these basic patches. A similar analysis also applies to Versions C and D. Hence, Version A is the basic color phenomenology.

Is there a fundamental approach of doing color phenomenology that results in the basic color phenomenology of a scene?

For the case of shadows, or of painted "shadows", or of projected "shadows", the method for obtaining Version A is to detach oneself from any first-order beliefs about the illumination of a scene and employ only the color concept, the object concept and phenomenological terms

[9] Of course, one can argue that different beliefs one holds might be differently weighted. This line of response does not help much to reject the point that Version A is better than the other versions, because Version A is insensitive to one's beliefs about illumination. At best, it only helps to the point that Version X ($X \neq$A) is better than Version Y ($Y \neq$A, $Y \neq X$).

like “appear”, “seem to be”, “look to be”, etc. To obtain Version A*, the object concept must also be abandoned.

In general, basic color phenomenology should be carried out in a way that is immune to one’s first-order beliefs about actual states of affairs as much as possible. This immunity arises from the second-order belief that there is almost no chance for the first-order belief about the illumination conditions of a visual scene to be correct if this first-order belief is suggested only by the scene itself.

The notion of the basic color phenomenology of a scene provides the foundation for many following discussions. In Section 5.2, it is used to substantiate one premise of the argument from content indeterminacy. In Section 5.5, it is employed to rebut an objection to the argument. In Section 7.4, it provides a crucial reason to reject various color objectivists’ characterizations of color constancy.

5.2 The Argument from Content Indeterminacy

Here is the *argument from content indeterminacy*:

Premise 1: If representationalism is true, in principle, a visual scene’s color phenomenology must guarantee the determinacy of its propositional content regarding colors.

Premise 2: It is not the case that, in principle, a visual scene’s color phenomenology must guarantee the determinacy of its propositional content regarding colors.

Conclusion: Representationalism is false.

The argument is logically valid. We examine its soundness. Premise 1 is assumed by representationalism. Even though it is not made explicit, representationalism relies on the underlying assumption of a certain relation between phenomenology and representational content. In the following, I primarily focus on Byrne and Hilbert’s representationalism. The conclusion can be generalized to other versions in the literature.

As mentioned, representationalism is the view that a visual experience is representational in the sense that a visual experience represents the external states of affairs by its propositional (or representational) contents. In the following, I will use “r-content” as the abbreviation for representational content. The phenomenal character of a visual experience is determined by (or identical with, or grounded in) its r-content in the sense that “[t]he representational content of a subject experience specifies the way the world appears to the subject” (Byrne and Hilbert, 2003: 5). And the veridicality or non-veridicality of the r-content is determined by the external states of affairs. As emphasized in the quotation, the way the world appears to be (or the phenomenal characters in the "appearances") is entirely specified by an experience's r-content.[10] However, all dyadic relations, including the one between phenomenal characters and r-content, can be considered in two directions. In one direction, the r-content of a visual experience determines its phenomenal characters in the sense that phenomenology is nothing over and above its r-content, and in the other direction, the phenomenology of a visual experience somehow guarantees the determinacy of the r-content, which further guarantees a determinate truth value of the content. The two-way relation is hinted at in the term "*if and only if*" used by Byrne and Hilbert in their formulation:

> In general, the proposition that p is part of the content of a subject's visual experience if and only if it visually appears to the subject that p. Propositions are bearers of truth and falsity: the proposition that there is a red bulgy object on the table is true just in case there is a red bulgy object on the table, and false otherwise. (2003: 5; my italics)

How phenomenology can guarantee the determinacy of r-content is not made explicit by Byrne and Hilbert. But it can at least be clarified. According to representationalism, visual experience is fundamentally representational. This means that it is necessary that a visual experience's being representational does not hold in virtue of any other facts. That is, as long as a visual scene is given, the r-content of an experience has a "truth" value: it is either veridical or non-veridical. The r-content of a visual experience and its veridicality or non-veridicality exhaust the nature of the experience. For a visual experience to have *a* "truth" value, its r-content must be determinate with regard to what is represented by the experience. Put another way, if the r-content of an experience is indeterminate, it is implausible that the experience can still be fundamentally representational.

The above general analysis of the relation between phenomenology and r-content is applicable to the relation between color phenomenology and representational content related to colors. *For a visual scene*, if the color phenomenology is that it appears to the subject that there is a red bulgy object, then the content of one's experience is that there is a red bulgy object. In this case, the determinacy of the r-content *regarding colors* immediately obtains due to the determinacy of the color phenomenology.

Therefore, we have validated Premise 1: if representationalism is true, then, in principle, *a visual scene*'s color phenomenology must guarantee the determinacy of its r-content.

[10] In this context, "phenomenal characters" and "the way the world appear to be" are terminological differences.

One more point about Premise 1: With "in principle", I intend to exclude the thesis that the indeterminacy of content arises from the alleged vagueness of color phenomenology. For instance, *for some visual scene* it might be said that it is hard to clearly classify the presented determinate color as either light yellow or orange. What follows is that r-content is indeterminate regarding the determinately presented colors. As opposed to Premise 1, this line of reasoning suggests that the vagueness of color phenomenology gives rise to the indeterminacy of r-content. Accordingly, Premise 1 cannot be firmly established.

The alleged vagueness of color phenomenology assumes that, for a given visual scene, rather than the directly presented determinate colors only determinable colors belong to the r-content.[11] I reject this assumption primarily because it conflicts with color phenomenology.[12] F*or a given visual scene*, the presented colors are always determinate. There is no vagueness problem regarding these phenomenally determinate colors. Even if there are determinable colors represented in a certain presentational sense, it is still impossible to discern determinable colors while not discerning any determinate colors. That is, color phenomenology does not support the assumption that the r-content of a color experience only involves determinable colors and excludes determinate colors. [13] I will not go into details in rejecting this assumption. At any rate, there is *no* vagueness problem regarding color phenomenology in Byrne and Hilbert's representationalism.

Now, we move to Premise 2. It denies that, *for a visual scene*, in principle, its color phenomenology can guarantee the determinacy of the r-content. There are two routes to substantiate Premise 2. According to the first route, the color phenomenology is indeterminate, whence the determinacy of its r-content is not guaranteed, as suggested by Travis and Chalmers.[14, 15] According to the second route, color phenomenology is determinate, yet this

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[11] A determinate color is maximally specific, such as a particular shade of red, whereas a determinable color specifies a certain range of determinate color, such as red. For this version of color objectivism, according to which colors are determinable, see Gert 2017.

[12] Besides, the assumption also presupposes that metaphysically, there are irreducible determinable colors that are more fundamental than determinate colors. This is a controversial assumption.

[13] For Byrne and Hilbert's representationalism, there is no vagueness problem regarding color phenomenology. For them, assuming that color phenomenology suggests that colors are always determinate is only their starting point for their further reductionist analysis of the related representational content. "To a first approximation, then, if someone with normal color vision looks at a tomato, the representational content of her experience is not simply that the tomato is red_{29} (suppose 'red_{29}' is a determinate shade of yellowish-red). Rather, the content is, for example, that the tomato has a value of R that is 80 percent of its total hue, and a value of Y that is 20 percent of its total hue" (2003: 14). Hence, for representationalists like Byrne and Hilbert, there is no vagueness problem with regard to color phenomenology.

[14] Travis (2004) argues against representationalism with the following reasoning: If it is true, then the representational content must be recognizable. But the representational content cannot be recognizable on the basis of how things look phenomenally. Thus, representationalism is false. Keith A. Wilson (2018) reformulates Travis' argument in a lucid manner which is supposed to dispel many misinterpretations from representationalists.

[15] Similarly, Chalmers (2006) claims that color phenomenology is indeterminate, whence the answers to questions such as "What is the representational content of a given color experience?" and "How would world

alone is still insufficient to guarantee the determinacy of r-content. I will demonstrate that Premise 2 works with both routes and suggest that the second route is better by the end.

We again take the case of shadows represented by Figure 5.1 as an example. How does the first route substantiate Premise 2?

The first route is that the color phenomenology is indeterminate such that it cannot guarantee the determinacy of the r-content. Namely, the indeterminacy of the r-content is inherited from that of the color phenomenology. As discussed, for the case of shadows, there are four plausible versions of the color phenomenology, Versions A, B, C and D. Even though Version A is favored, there is no *a priori* reason to rule out any of them. As for the relation between color phenomenology and r-content, we follow Byrne and Hilbert's view: "In general, the proposition that *p* is part of the content of a subject's visual experience if and only if it visually appears to the subject that *p*" (2003: 5). Accordingly, for the case of shadows, we can logically have four views of its r-content corresponding to the four versions of its color phenomenology. How should we analyze these four views of the r-content?

If we simply assume that a proposition can be specified in the form "a certain object has certain properties", we have the following results: The Version-A-related r-content is that the wall has two colors, white and gray. The Version-B-related r-content states that the wall has one uniform white. The Version-C- and -D-related r-contents also describe the wall as having two colors, white and gray. The four views of the r-content differ on the number of colors of the wall: the Version-B-related r-content identifies one, the others say two. Since the color phenomenology is indeterminate regarding the number of colors, the r-content is indeterminate in that respect too. Hence, Premise 2 is validated.[16]

Now we focus on the second route. For the case of shadows, how does the second route substantiate Premise 2?

The second route is that color phenomenology is determinate but still insufficient to guarantee the determinacy of the r-content. There is an indeterminacy in the guarantee relation. As discussed in Section 5.1, for the case of shadows, there are four plausible versions of the

have to be for a given color experience to be veridical?" are indeterminate. Chalmers (2006) defends a hybrid view of representationalism, according to which the indeterminacy of color phenomenology is not a problem. The indeterminacy of color phenomenology results from the indeterminacy of different theoretical descriptions of color phenomenon within the framework of representationalism. This is not a challenge to Chalmer's representationalism but rather a challenge to externalist representationalism.

[16] If we add some complexities to the way a proposition is specified, it is much easier for us to get the same conclusion. For instance, if we further allow the metaphysical nature of color properties to figure in the formulation of a proposition, such as "is illumination-dependent", it is easy to anticipate that the contrast between these views of p-content will become more obvious. There is no need to unfold the reasoning. We can draw the same conclusion that color phenomenology is indeterminate and thus cannot guarantee the determinacy of the p-content. Premise 2 is validated.

color phenomenology, Versions A–D. Although there is no *a priori* reason to rule out any of them, there are decisive reasons to favor Version A. As established, Version A constitutes the basic color phenomenology of the case of shadows. Whenever a visual scene is given, its basic color phenomenology obtains determinately and it is immune to the possible incorrectness of one's beliefs about illumination, that is, it cannot fail. Other, non-basic versions of the color phenomenology, by contrast, may turn out to be incorrect. Thus, it is reasonable to assume that Version A is *the* color phenomenology of the case of shadows. Given this, here is an analysis of how the *determinacy* of color phenomenology is still insufficient to guarantee the determinacy of r-content.

Version A is that the wall appears to have two colors, white and gray. The upshot of it is that wherever there appears to be a shade pervading on the wall, there appears to be a color. The corresponding experiential content suggested by Version A is that the wall has two colors. However, is this experiential content the r-content required by representationalism?

Recall Byrne and Hilbert's formulation of the premise of representationalism: "[F]or instance, tomatoes do not seem to change color when they are taken from a sunny vegetable patch into a kitchen illuminated with incandescent light. Assuming that our perceptions of color are often veridical, we therefore need a physical property of objects that is largely illumination-independent – a physical property that an object can retain through changes in illumination" (2003: 9). It is hard to claim that the experiential content suggested by Version A is the r-content required by representationalism, because the experiential content suggested by Version A does not concern whether the wall has a stable color, which is involved in the r-content required by the representationalism.

The basic color phenomenology of a scene allows that all shades are candidates for real colors, while representationalism assumes that there are standard shades that figure in r-content as the real colors attributed to objects under standard illumination conditions. Put another way, according to the basic color phenomenology of a scene, the represented colors are illumination-dependent, while according to representationalism, the represented colors are illumination-*in*dependent and are intrinsically possessed by objects. These two notions of content conflict with each other. Hence, we can conclude that even if color phenomenology is determinate, that is still insufficient to guarantee the determinacy of r-content. Premise 2 is validated.

A summary of where we are: Currently, we have two routes for substantiating Premise 2. Although for different reasons, we can demonstrate via both routes the point that it is not the case that, *for a visual scene*, its color phenomenology guarantees the determinacy of the r-content of the visual experience. Combined with Premise 1, we can conclude that representationalism is false.

One final remark about the choice between the two routes. Whichever route is chosen, the conclusion remains the same. However, it is reasonable to advocate the second route because it delves deeper into the color phenomenology, compared to the first route. The second route is supported by the basic color phenomenology of a scene as established in Section 5.1, which is obtained via the basic way of doing color phenomenology.

5.3 Phenomenology with the Color–Illumination Distinction?

How do reflectance physicalists respond to the argument? Since they agree with Premise 1, they must deny Premise 2. This section elucidates their most compelling objection to Premise 2 and identifies one key assumption underlying it.

What I take to be the most compelling objection to Premise 2 is that a certain version of color phenomenology which can guarantee the *determinacy of* r-content can be naturally fixed in a determinate way so long as a visual scene is given. From this follows the falsity of Premise 2. "Naturally fixed" means that the color phenomenology of a scene is *naturally* given by one's intuition of the scene. For instance, in discussing the color phenomenology of a red rucksack partially illuminated by sunlight, the reflectance physicalist Tye claims:

> Surely, the *natural* account is that the differently illuminated areas of the rucksack look the same and also look different. They look the same in that the different regions look to have the same surface color—red. They look different in that the different regions look differently illuminated. Some parts of the rucksack appear to be in shadow. Other parts appear to be in direct sunlight. Visual experiences, thus, carry information about both color and illumination conditions. (2012: 303; my italics)

Tye assumes that there is a natural color phenomenology of the scene. In my terminology, it is naturally given by one's intuition of the scene. Call it the intuitionist color phenomenology.

The above objection is the most compelling one because the intuitionist color phenomenology highlighted by the objection is widespread in the color debate. It is favored mainly by color realists and is used in various ways to defend different color theories. For instance, the intuitionist color phenomenology is explicitly favored by Johnston (1992), Chalmers (2006), Tye (2012) and Allen (2016), who all argue for different color theories.[17] I will not get into the subtleties of how it can be employed in different color theories. For the current purpose, I will focus solely on Tye's color phenomenology, as representative of reflectance physicalists' views.

First, the determinacy of the intuitionist color phenomenology guarantees the determinacy of r-content. In cases such as a painted "rucksack", where there is no visual clue about the actual illumination conditions, although the r-content suggested by this color phenomenology might prove to be non-veridical, the non-veridicality of the content does not cancel its determinacy.[18] The upshot is that, when a scene is given, one intuitively associates with it a determinate color phenomenology that guarantees the determinacy of the r-content. Accordingly, Premise 2 would be false.

Second, the intuitionist color phenomenology is based on the assumption that visual experiences "carry information about both color and illumination conditions" (2012: 303). Call this the color–illumination distinction (CID) assumption. For instance, in Tye's example, the visually carried information can tell us which region of the rucksack is in shadow and which region is directly illuminated, say, by sunlight. The CID assumption is extremely important for evaluating representationalism. If this assumption is false, then the intuitionist color phenomenology is false. From that follows the falsity of representationalism. The rest of the chapter will discuss the CID assumption.

5.4 The Argument against the Color–Illumination Distinction Assumption

This section rejects the CID assumption. Specifically, I will present an argument against this assumption and conclude that a visual experience does not carry the information of CID at all.

To start with, if the CID assumption is true, a visual experience must carry the information of CID either in a global or in a local sense. Here, "global CID" means that CID applies to *all* regions of a visual scene, and "local CID" means that CID applies only to certain regions.

[17] Johnston (1992) defends color dispositionalism by listing the intuitive beliefs about color suggested by color experience. Chalmers (2006) defends a hybrid view of color. In his defense, he expresses his preference of the intuitive appeal of a certain color phenomenology, but still insists that there is no determinate answer to the question which version of color phenomenology is decisively superior. Tye (1995) defends color physicalism, but in his 2012 he responds to Cohen's color relationalism (2009) by emphasizing the naturalness of a certain color phenomenology. Allen's (2016) color primitivism is based on a certain phenomenological characterization of color constancy phenomena.

[18] The analysis can be generalized to the cases associated with shadows. When the case of shadows is given, Version B has the most intuitive appeal, and this implies the determinacy of the Version-B-related r-content. When the case of a painted shadow is given, Version C has the most intuitive appeal, so follows the determinacy of the Version-C-related r -content. This is so even if in some cases where there is no visual clue about the illumination conditions, the representational content might prove to be non-veridical. The non-veridicality of the representational content does not influence its determinacy. Thus Premise 2 is wrong.

The first challenge concerns the CID assumption in its global sense. The reasoning is that, in some cases, given that there is no visual distinction between the colors of an *illuminant* (or light source) and the illumination conditions under which the illuminant is perceived, it follows that a visual experience does not necessarily carry the global CID. For instance, when one turns on a computer and looks at its screen (an illuminant) in a dark room, one's visual experience cannot distinguish which aspects are the colors of the screen and which are the illumination conditions, because there is no way to distinguish the two aspects. Accordingly, the CID assumption in its global sense is incorrect.

The defenders of the CID assumption might not consider the above challenge as a decisive rejection. They might claim that the CID assumption is not about CID regarding an illuminant but rather about CID regarding a particular area of the object's surface. Accordingly, the CID assumption in its local sense still holds.

In the following, I will present an argument against the CID assumption in both its global and local senses. Call it the argument against the CID assumption.

P 1: The objective spatial information about illumination conditions is fundamentally three-dimensional (3D).

P 2: If the CID assumption is true, then in good cases, the visual experience of a given scene carries the objective spatial information about the illumination conditions.

Sub-conclusion: If the CID assumption is true, then in good cases, the spatial information about the illumination conditions carried by a visual experience of a given a scene is 3D.

P 3: In good cases, the spatial information about the illumination conditions carried by a visual experience of a given scene is fundamentally two-dimensional (2D).

C: The CID assumption is false.

As a preliminary step, I clarify some concepts. "Dimensional" means the spatial dimensionality supported by the intuitive distinction among length, width and height (or depth).[19] On this definition, a shade is 2D, since it lacks depth. An ordinary object, like an apple, is 3D, since it is extended in all three spatial dimensions. "Fundamentally three-dimensional" means that the number of dimensions that are needed to characterize the

[19] Strictly speaking, the intuitive distinction is not geometrical. The geometrical distinction between length, width and height requires a standard for measurement. This intuitive distinction is primarily based on one's intuitive spatial awareness. For instance, when one is walking, one has an intuitive spatial awareness that one's body is moving in a 3D space.

objective spatial information is three. “The spatial information carried by a visual experience is fundamentally two-dimensional” means that the number of dimensions needed to characterize the spatial information carried by a visual experience is two.[20] For instance, a shade presented in a visual experience is fundamentally characterized by 2D information: variations in length and width. Note that visual space being inherently 2D has to be distinguished from additional questions related to the notion of “experiential content”, like “Is the experiential content of a visual experience 3D?” If it eventually proves that visual space is 2D, it might still be the case that experiential content is 3D. This depends on how one understands the nature of experiential content. Here, I treat the notion of “experiential content” as a placeholder open to further options, such as externalist representational content, internalist representational content, idealist world-suggestive but non-representational content, etc.

The argument is valid. We examine its soundness. P 1 is conceptually true. Based on the above clarification of “dimensional”, illumination conditions are 3D. For instance, in the case of the shadows represented by Figure 5.1, the illumination conditions consist in the specific spatial relation among the illuminant, the leaves that block the light and the wall. All three elements are 3D objects and their spatial relations are 3D, too.

P 2 is true according to the CID assumption. For instance, in Tye’s example, the CID assumption tells us that the visual experience carries the information of which region of the rucksack is in shadow and which region is directly illuminated by sunlight. This entails that, in good cases, a visual experience carries the objective spatial information about the illumination conditions.

The Sub-conclusion follows from P 1 and P 2.

The critical premise is P 3. What makes the spatial information about the illumination conditions in a visual experience fundamentally 2D? The answer lies phenomenology.

To begin with, it is worth mentioning one line of eliminativist physicalists’ (or internalist representationalists’) reasoning that can lead to P 3. According to it, due to the assumption that a visual experience is no different from a brain state that is ontologically caused by the mind-independent world, and the assumption that a visual experience is *exhausted* by its mental qualia, which are non-relational, non-representational 2D formats the visual experience, it follows that the experiential characterization of the world is neither externally representational nor 3D. Hence, the spatial information carried by a visual experience is

[20] In comparison, an ordinary object presented in tactile experience is characterized by three dimensions, length, width and height.

fundamentally 2D because mental qualia are 2D.[21, 22] My agreement with this line of reasoning is limited. I agree only with its phenomenology and remain silent on its metaphysics (or ontology). The point is that the eliminativist physicalists' (or internalist representationalists') phenomenology can be established independently of their ontological assumptions. In short, this phenomenology has its own independent grounds for validity. A similar analysis was demonstrated in Section 5.1.

Here is my validation of P 3.

Analyzing the dimensionality of illumination conditions in a visual experience can be simplified to analyzing the dimensionality of the simplest illumination condition in a visual experience. The simplest illumination condition is constituted by a spatial relation among three objects: an illuminant, a blocker and a material object. This suggests that the analysis can be further simplified to examining the dimensionality of objects in a visual experience. Accordingly, I will consider observations of visual experiences with ordinary objects which suggest that the spatial information about objects in a visual experience is fundamentally 2D. This, in turn, indicates that the illumination conditions in a visual experience is fundamentally 2D.

What is the appropriate phenomenology of visual experiences of ordinary objects, using someone viewing an ordinary apple in daylight as an example?

Intuitively, one might characterize this scene as the apple's surface appears red under daylight conditions. This phenomenology is guided by the subject's belief that there is an apple that is being viewed under daylight conditions. This guidance allows one not only to speak of the color appearance of "something real thing", like "the color appearance of an apple", instead of merely speaking of "a color appearance", but also to speak of the actual illumination conditions.

However, the above phenomenology is not strict. As established in Section 5.1, a strict phenomenology should be carried out in a way that is immune to one's beliefs about the environment as much as possible. This is precisely captured by the basic phenomenology of

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[21] For discussion of qualia, see Block 2003 and Papineau 2021. Block (2003) claims that a visual experience is representational, but that the phenomenal character of the experience cannot be exhausted by its representational content due to the additional existence of qualia. Papineau (2021), by contrast, claims that a sensory experience is non-representational because it is exhausted by qualia that are mere non-representational formats.

[22] Here, the line of reasoning mentioned in the main text is in the same spirit as Papineau's view. "The internal organization of sensory experience might invite the belief that it essentially relates us to independent objects and properties beyond ourselves. But this invitation must be declined. Sensory experience is not really relational" (Papineau 2021: 84). "As I see it, *no* conscious sensory properties can be equated with the property of representing some worldly condition. My view is that conscious sensory experience is *all* paint (plus possibly some blurry, orgasmic, etc. oil)" (ibid., 86). The additional point we attach to Papineau's view is that qualia are two-dimensionally characterized.

a given scene, suggested by the basic way of doing color phenomenology. That is, it is better if a phenomenology does not involve objects and illumination conditions. For the case of the apple, the basic phenomenology is that there are 2D red patches (or that there are 2D apple-like patches).[23] This phenomenology suggests that there are two and only two spatial dimensions that characterize the color appearance of an apple. (It is in the same spirit as Version A* discussed in Section 5.1.) In sum, it suggests that spatial information about objects presented in a visual experience is fundamentally 2D.

As discussed, the above result can be straightforwardly generalized to the dimensionality of illumination conditions in a visual experience. Namely, the spatial information about the illumination conditions in a visual experience fundamentally 2D. This can be further strengthened by the following analysis.

We start with an analogy. Figure 5.2 is a representation of a realist painting of an apple that casts a shadow on a floor.[24] The painting is drawn on a 2D plane, consisting of a painted shadow and a painted color appearance of the apple's surface as viewed from a certain angle at a certain distance. Although there *seems* to be a 3D, illuminated apple, it is obvious that the spatial information conveyed by visual experience of the painting is 2D. Due to the 2D plane, there is no additional third dimension.

Likewise for visual experiences with illumination conditions, what a visual experience presents is an arrangement of 2D shades. Take the case of the shadows represented in Figure 5.1 as an example. The objective spatial information about illumination conditions is a 3D relation between the illuminant, some leaves and the wall, which are not presented in the 2D color shades (or formats) of the visual experience. The spatial information of one additional dimension (the depth information) is lost. Although there appears to be a 3D spatial relation between the illuminant, some leaves and the wall, this information in not presented in the visual experience at all. Hence, P 3 is substantiated.

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[23] The use of the word "apple" in the characterizations does not rely on the ontological assumption that there is an actual apple; it only employs the apple concept.
[24] The source of the picture is https://steemit.com/art/@hiddenblade/how-i-paint-an-apple-a-digital-painting-step-by-step-guide.

Figure 5.2: A realist painting of an apple.

Therefore, we arrive at the conclusion of argument: the CID assumption is false.

This is a decisive rejection of the CID assumption, since it applies to both its global and local senses. From this follows the falsity of the intuitionist color phenomenology. The reflectance physicalists' objection to the argument from content indeterminacy is rejected.

5.5 A Lost Dimension: Imaginary Visual Depth

In this section, I discuss an objection to the argument against the CID assumption. The objection is: Given that illumination conditions are objectively 3D, how could it be the case that, in a given scene, the spatial information carried by a visual experience regarding the illumination conditions is 2D? How does 3D objective space manifest in the phenomenology of a visual scene in a 2D way? In short, how can we make sense of the loss of one dimension? Without a clear explanation, accepting a 2D visual phenomenology is unreasonable.

Note that the objection formulated above can scarcely be found among contemporary philosophers. The main reason seems to be that the CID assumption is rarely challenged and there is a widely shared belief among philosophers that a visual experience indeed carries 3D information about states of affairs.[25] Accordingly, visual phenomenology would not be reducible to a 2D color phenomenology. In contrast, among scientists, the view that visual phenomenology is a 2D color phenomenology is much more popular.[26] For instance, the

[25] Howard Robinson's work (2022) is a rare exception. He emphasizes the oddities of visual depth and fairly summarizes what one can agree on about visual depth despite the oddities: "It is enough that (a) depth has a phenomenological manifestation and (b) that it thereby presents objects, fairly accurately, as being the distance they actually are away from us" (2022: 133). I agree with the summary, which is compatible with the point that the nature of visual depth is imaginary. But Robinson does not further investigate whether or not the oddities of visual depth can be safely set aside if one is stricter about the notion of veridical experience. My view is that, in principle, the oddities of visual depth experience cannot be set aside. As a consequence, I find a notion of veridical experience is implausible.

[26] The view seems to be endorsed also by traditional idealists. For instance, George Berkeley writes, "In a strict Sense, I see nothing but Light and Colours, with their several Shades and Variations" (2002/1732, CXXX).

theoretical physicist and color scientist Maxwell claims: “All vision is colour vision, for it is only by observing differences of colours that we distinguish the form of objects. I include differences of brightness or shade among differences of colour” (2010: Vol. 2, 267).

In due course I will, in response to the above questions, first explain why one dimension of space is lost in visual perception. Second, I will explain why there still appears to be 3D space presented in a visual experience, by discussing the imaginary nature of visual depth.

My explanation of the loss of one dimension in vision is that the objective 3D spatial information, when presented in a 2D way in visual experience, cannot be presented in such a way that it can be differentiated from its 2D mode of presentation. To illustrate the point, consider the case of shadows as an example.

In the case of shadows, there is an objective 3D spatial relation, R_{3d}(illuminant A, object B, shadow C). When one does the phenomenology of this case, one’s visual experience only presents 2D shades. There might be a combination of certain shades, R_{2d}(shade A, shade B, shade C), which is cognitively interpreted as a marker of the objective 3D spatial relation, R_{3d}(illuminant A, object B, shadow C). The crux is that there is no way of *visually* differentiating R_{3d}(illuminant A, object B, shadow C) from its 2D mode of presentation, R_{2d}(shade 1, shade 2, shade 3). More precisely, any differentiation of the spatial dimensionality of what is objectively presented in a visual experience is necessarily reduced to the differentiation between the two-dimensionally arranged color shades. In principle, merely based on visual phenomenology, no differentiation between R_{3d}(illuminant A, object B, shadow C) and R_{2d}(shade 1, shade 2, shade 3) can be made. There is a loss of one dimension. Strictly speaking, visual phenomenology is just a 2D color phenomenology.

But why does there still appear to be 3D space, rather than 2D space, presented in a visual experience?

My answer is that the visual depth in a visual experience is imaginary. In the following, I will show that the imaginary nature of visual depth (in a global or a local sense) is well captured by the 2D color phenomenology, which is reflected by its being embedded in the visual width and length in various ways. “Imaginary” implies that visual depth does not really exist but is instead a construct derived from the other two visual dimensions, without necessarily correlating to the objective depth of a scene.

As will become clear, many clues of a visual experience suggest that the visual depth is only imaginarily given, while the visual length and width are directly given.[27] Although many visual clues seem to make visual depth appear as real as the other two dimensions, its

[27] Note that this point is different from the point that visual depth is inferred from background beliefs.

imaginary nature can still be gleaned from some clues embedded in the information about the other two dimensions. Here are five examples of different kinds.

For the first kind, the imaginary nature of visual depth can be noticed in the basic use of 2D color phenomenology. Most of our visual experiences in everyday contexts belong to this category. For instance, when one has a visual experience of an ordinary object such as a host computer, what one visually attends to is just 2D color appearances that give one an impression of the depth of a host computer. Compare this phenomenology with the following example (see Figure 5.3), which is a picture of a host computer such that its phenomenology is the same as in the previous case. One has the same impression of depth of a putative host computer by noticing the same 2D color appearance. The comparison shows that the 3D visual impression of a scene is constructed out of the 2D color appearance. Although a visual experience might invite a (possibly true) belief about a 3D space, it does not carry information about an objective 3D space.

Figure 5.3: A picture of a host computer.

For the second kind, the imaginary nature of visual depth is exposed by local indeterminacies between different visual depths. For instance, see Figure 5.4, a photo of contrails left by two airplanes which appear to be crossed. When one looks at the sky, one has an impression of a 3D sky and an impression of four 2D blue regions demarcated by two crossed white lines. For this scene, the imaginary nature of global visual depth can be noticed in the basic use of 2D color phenomenology: the additional visual depth of sky is embedded in the 2D blue regions. The imaginary nature of local visual depth is suggested by the local indeterminacies between different local visual depths embedded in the 2D color phenomenology.

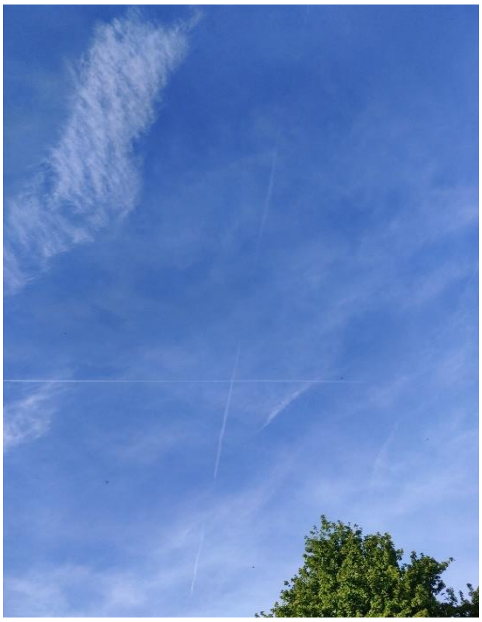

Figure 5.4: Cross appearance of two contrails.

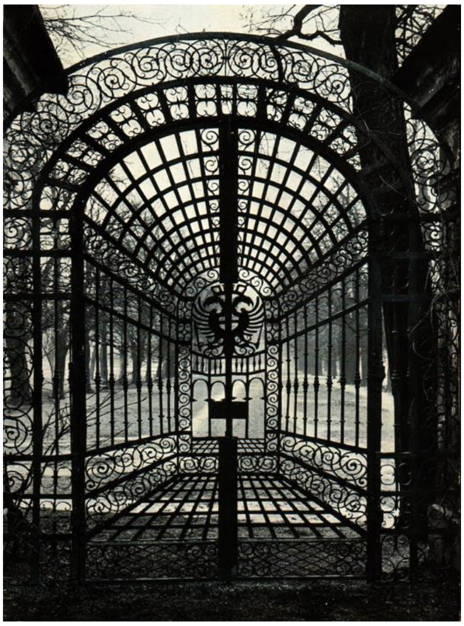

Figure 5.5: A photo of a gate in Vienna.[28]

For the third kind, the imaginary nature of global visual depth seems to be weakened by the imaginary local visual depth, which conversely makes the imaginary global visual depth appear more real. For instance, see Figure 5.5, a photo of a gate in Vienna. When one looks at the gate, what is visually presented is a 2D color appearance that gives one a global 3D impression of a normal gate located before a garden. However, when one pays attention to the local normal gate embedded in the global 3D impression, interestingly, one has an impression of a corridor gate extending further into a garden. For this scene, the imaginary nature of global visual depth can be noticed in the basic use of 2D color phenomenology: the additional visual depth of the scene is embedded in the 2D color appearance. Importantly, the imaginary nature of global visual depth seems to be weakened by the imaginary local visual depth, because the latter is structurally embedded in the former, making the former appear more real.

For the fourth kind, the imaginary nature of visual depth is partially revealed by the imaginary local visual depth, which makes the imaginary global visual depth less imaginary. For instance, look at Figure 5.6, a photo of M. C. Escher's painting "Waterfall" (1961). When one looks at the painting, what is visually presented is a 2D color appearance that gives one a global 3D impression of a watermill consisting of houses, a waterwheel and an aqueduct. However, when one closely looks at the local aqueduct, one has an impression of an aqueduct fed by, and leading to, a watermill, and interestingly, this generates a self-inconsistent impression of the local depths: If one focuses on the waterwheel and the nearby aqueduct, the

[28] The picture is a representation of the gate of Theresianum Academy. The copyright belongs to https://mymodernmet.com/optical-illusion-gate-theresianum-academy/.

impression is of the aqueduct extending horizontally *behind* the waterwheel. If one focuses on the waterwheel and the falling water, however, the impression is one of the aqueduct's mouth being vertically *above* the waterwheel. For this scene, the imaginary nature of global visual depth can be noticed in the basic use of 2D color phenomenology: the additional visual depth of the scene is embedded in the 2D color appearance. Importantly, the imaginary nature of global visual depth is partially revealed by the imaginary local visual depth, because the self-inconsistent impression of the latter makes the former appear unreal.

Figure 5.6: Escher's waterfall.

Figure 5.7: Infinite "mirrors".[29]

For the fifth kind, the imaginary nature of visual depth is plainly disclosed by the imaginary local visual depth by its bizarre recursive structure. For instance, look at Figure 5.7, which is a photo of a mirror which has another mirror opposite to it. When one looks at the mirror, what is visually presented is a 2D color appearance that gives one a global 3D impression of a mirror. However, when one scrutinizes the local middle part of the mirror, one has an impression of recursively iterated an infinite series of ever smaller, ever more distant mirrors, which is bizarre.[30] For this scene, the imaginary nature of global visual depth can be noticed in the basic use of 2D color phenomenology: the additional visual depth of the scene is embedded in the 2D color appearance. Importantly, the imaginary nature of global

[29] The source of the picture is
https://www.wikiwand.com/en/Infinity_mirror#Media/File:Infinity_mirror_in_a_public_bathroom.jpg

[30] Describing a specific phenomenology for this case is difficult. On the one hand, it could be said that the imaginary nature of visual depth in the global sense is made more real by the local clues, since the visual depth seems to extend into infinity. On the other, it could be said that the imaginary nature of visual depth in the global sense is made more unreal by the local clues, since the recursive iteration itself seems unreal in the sense that it is difficult to understand the recursive structure of this visual depth.

visual depth is plainly disclosed by the imaginary local visual depth, because the recursive structure of the latter makes the former seem utterly unreal.

To conclude, these five examples illustrate that the imaginary nature of global visual depth can be noticed via the basic use of 2D color phenomenology, and that there are different ways in which the imaginary visual depth is embedded in the information about the other two dimensions. The last three examples make the point more striking. It follows that even though a 3D space appears visually present, the visual depth in visual experiences is imaginary.

6

Black

This chapter examines the causal premise of the Color Thesis of reflectance physicalism. Recall the premise: "Any plausible version of physicalism will identify the colors with physical properties implicated in the causal process that underlies the perception of color" (Hilbert and Byrne 2003: 8). It suggests that, first, one must find colors in the causal process underlying the perception of color, and, second, colors, as physical colors, are causally efficacious. Regarding the first point, one might naturally wonder whether all colors can be found in the causal process underlying the perception of color. If black is a color, does black also reside in the causal process underlying an experience of black? For instance, when one sees a total solar eclipse, there seems to be no causal process underlying one's experience of black. Regarding the second point, given that reflectance physicalists identify colors with SSRs, which are dispositional properties, there is a general problem of the causal inefficacy of dispositional properties. For instance, consider a vase, which is fragile: when hit properly it breaks. It seems that the molecule bonding and the external force impinging upon it provide a sufficient causal explanation, which leaves no place in the causal explanation for the dispositional property of being fragile. One might similarly wonder: are SSRs, being dispositional properties, causally efficacious?

This section will explore these two points, with the primary focus on the first. It is structured as follows: in Section 6.1, I explain what it means for colors to be physical, as implied by the causal premise. Section 6.2 focuses on an empirical correlation related to some phenomena of the color black: black experiences are correlated with the absence of causal processes. Section 6.3 presents the argument from the color membership of black, concluding that reflectance physicalism is false because it cannot consider black as a color. In Section 6.4, I respond to three objections to the argument. Section 6.5 examines whether SSRs, the physical correlates of colors suggested by reflectance physicalists, are causally efficacious.

6.1 The Causal Premise

The causal premise is the most fundamental premise of reflectance physicalism. It relies on a causal notion of physical colors that is based on two assumptions: (i) colors are physical properties, (ii) physical properties are causally efficacious. Assumption (i) is explicitly included in the causal premise, while (ii) is a tacit background assumption.[1] Combining (i) and (ii), the nature of physical colors can be exhaustively characterized by their causal roles (or causal relations) to other properties. We then have a sufficient and necessary condition for a color being physical. Call it *the physicality condition for colors*.[2]

The physicality condition for colors: A color is a physical color if and only if it is a property that can fulfill the causal role of producing the related color experiences.

This condition is of great importance in evaluating the relation between the causal premise and SSR, which is connected with a significant issue in the metaphysics of dispositions: the problem of the causal efficacy of dispositions. Considering that SSRs are dispositional properties, one can ask: given this condition, can SSRs, as dispositional properties, fulfill causal roles of physical colors?

Some color objectivists believe that SSRs are physical colors and are also causal because SSRs, qua dispositional properties, are causal.[3] Some believe that SSRs are *not* physical colors, because SSRs, qua dispositional properties, are *not* causal.[4] Some believe that SSRs are physical colors and are causal in the sense that SSRs are involved in the same event that includes their causal bases.[5] Some believe that dispositional properties are causal and that colors are dispositional properties, but that SSRs are not colors.[6] I will set aside the controversies surrounding the problem of the causal efficacy of SSRs for now and revisit them in Section 6.5.

What is relevant for the discussion in Sections 6.2–6.4 is the necessary condition for colors' physicality: a color is a physical color only if it is a property that can fulfill the causal role of producing the related color experiences.[7] It is very useful in evaluating reflectance physicalism since it is open to counterexamples which show that a certain color is not a

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[1] Another way to make sense of (ii) is that it is a consequence of the thesis of the causal closure of the physical, according to which every physical event has a physical cause. A physical event is causally efficacious if and only if there are physical properties in the event that play a causal role or have causal relations with other physical events. The thesis of the causal closure of the physical is a typical assumption of physicalists. For some physicalists, to be physical is to be efficacious. See Papineau 2001 for a discussion of physicalism that is based on the thesis of the causal closure of the physical.

[2] These two points are clearly captured in Byrne and Hilbert's, Lewis' and Jackson's formulations of the causal premise. For Lewis' and Jackson's formulations, see Section 6.5.

[3] This is Byrne and Hilbert's (2003) view.

[4] See Jackson 1996.

[5] See Lewis 1997.

[6] This is what a color dispositionalist would believe, see McGinn 1982.

[7] The point is also plainly suggested by the premise, which claims that it is only in the causal process underlying the relevant color perception that one can find physical colors. Put another way, being involved in the causal process underlying the color perception so caused is a necessary condition for a property to be a physical color.

physical color. If a counterexample shows that there is a color which *cannot* fulfill any causal role, then that color is not a physical color. As a result, reflectance physicalism cannot account for all colors. Thus, given that a color theory is supposed to include all colors, we have a strong reason to doubt whether reflectance physicalism is a color theory at all. As will become clear, black is just such a color which is not included in reflectance physicalism. But before presenting the argument, I will first focus on an empirical correlation regarding black.

6.2 An Empirical Correlation

Let us start with two examples of the color black phenomena (see Figure 6.1 and Figure 6.2).

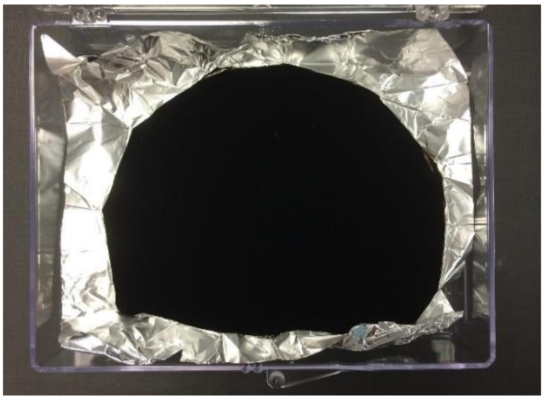

Figure 6.1: A Vantablack object.[8]

Figure 6.2: A total solar eclipse.

Figure 6.1 is a representation of a Vantablack object. Vantablack is a substance made of carbon nanotubes which is said to be "the world's darkest material"; it absorbs a maximum of 99.965% of radiation in the visible spectrum, which is more than any other material absorbs. When one sees a Vantablack object, one still has a vivid black experience despite the (almost total) absence of a causal process underlying the experience of black. Loosely speaking, the visual experience one has with Figure 6.1 only "mimics" the visual experience one has with a real Vantablack object, which seems less like a black object than a hole into nothingness.[9]

Figure 6.2 is a picture of a total solar eclipse. A total solar eclipse occurs when the Moon passes exactly between the Earth and the Sun. It can be observed in a specific region of the Earth when that region is aligned directly with the Moon and the Sun. When one observes a total solar eclipse, one has a vivid black experience despite the absence of a causal process underlying the experience of black.

[8] The object is presumably coated with Vantablack and lies on a sheet of aluminum foil. The source of the picture is https://www.wikiwand.com/en/Vantablack#cite_note-3.
[9] Strictly speaking, the visual experience you have with Figure 6.1 is not the same as the experience you have with real Vantablack, since there is still a small amount of light reflected from the dark portions of the picture you see.

These two examples obviously suggest that black experiences are correlated with the *absence* of causal processes.[10] Note that the relevant sort of causal processes are ones involving electromagnetic waves in the visible spectrum.[11] Moreover, this correlation is supported by the intuitive reasoning: Visible light causes *non*-black color experiences. When there is no visible light, the related causal process is absent, yet a vivid black experience still remains. Therefore, black experiences are correlated with the *absence* of causal processes.

These examples are not ordinary cases. What about ordinary black objects? Does the above correlation persist? In ordinary cases, the absence of a causal process comes in degrees, but this does not mean that there is no such correlation. Actually, the correlation between the absence of a causal process and the presence of a black experience is ubiquitous. Here are two everyday cases. For one thing, the pixels on the screen of a computer can be turned off to stop the causal process underlying one's color experience, but one retains a vivid black experience of the screen. For another thing, the printing ink printed on a page in a book is arranged such as to absorb as much light as possible, in order to stop the causal process of light reflection, but one retains a black experience of the words on the page. In these two examples, causal processes are not totally absent (namely, certain extremely weak causal processes underlying the black experiences remain).[12] But they still support the above-mentioned correlation in the sense that if a weaker causal process is involved, the more vivid one's black experience becomes. Hence, the correlation still holds in everyday cases.

Therefore, it is empirically given that the absence of a causal process correlates with the presence of a black experience.

6.3 The Argument from the Color Membership of Black

In this section, I present an argument according to which, in reflectance physicalism, black cannot be considered a color. Call it *the argument from the color membership of black*. It relies

[10] Strictly speaking, in these two examples there could well still be extremely weak rays of light, but they are not sufficient to elicit color experiences in the same way in which color experiences are elicited when there is sufficient visible light.

[11] Of course, this does not imply the absence of all causal processes whatsoever. There might still be other causal processes, regarding wavelengths in the invisible part of the spectrum, like ultraviolet. If we take the triples of reflectance integrals into consideration, then the notion "the absence of a causal process" applies to the wavelengths in the three intervals for the triples of reflectance integrals. Our visual system is not equally sensitive to all wavelengths in the visible spectrum, but only sensitive to three overlapping intervals of different wavelengths in the visible spectrum. The overall effect of these different sensitivities of our visual system to different intervals of wavelengths is called the triples of reflectance integrals. For the sake of simplicity, I leave aside these complexities here. If we took them into account the argument would be similar.

[12] In the case of the pixels, even though the pixels stop emitting light, the material made up of the pixels still reflects light to some extent. In the case of the pigments, though pigments absorb large amount of light, they still reflect light to some extent.

on the idea that black is a color that exists independently of the causal process underlying ordinary color experiences. The argument is as follows:

Premise 1: If a color theory is true, then it explains the nature of all colors.
Premise 2: Reflectance physicalism is a color theory.
Premise 3: Black is a color.
Premise 4: Reflectance physicalism cannot explain the nature of black.
Conclusion: Reflectance physicalism is false.

The argument is valid. We examine its soundness. Premise 1 is conceptually true: "a color theory" means a theory about *all* colors. Premise 2 is also conceptually true. The conjunction of Premise 1 and Premise 2 implies that reflectance physicalism explains the nature of all colors.

Premise 3 is validated by the following observation: That black is a color is a conventional truth. For instance, in the *Oxford English Dictionary*, the first meaning of "black" is "of the darkest color possible".[13] In Wikipedia, the entry for "black" begins: "Black is a color which results from the absence or complete absorption of visible light."[14] Moreover, we pre-theoretically believe that black is a color, just like green, which is widely accepted as true. Hence, "black is a color" is conventionally true.

Given Premises 1–3, reflectance physicalism can explain the nature of black.

Premise 4 states that reflectance physicalism *cannot* explain black. This can be validated by considering the necessary condition for colors' physicality (established in Section 6.1) and the correlation between the absence of a causal process and the presence of a black experience (established in Section 6.2). The reasoning is as follows.

According to the necessary condition for colors' physicality, a color is a physical color only if it is a property that can fulfill the causal role of producing the related color experiences. Accordingly, for reflectance physicalism to be true, black must fulfill the causal role of producing the related black experiences. However, it is an empirical fact that the presence of a black experience is correlated with the *absence* of a causal process. This straightforwardly suggests that the presence of a black experience depends on the absence of a causal process. Put another way, the presence of a black experience cannot be caused by black because there is no causal process underlying the black experience. Thus, black cannot satisfy the necessary

[13] "black". OED Online. March 2023. Oxford University Press. See https://www.oed.com/view/Entry/19670?rskey=lfQfQ0&result=1.
[14] See https://www.wikiwand.com/en/Black

condition for colors' physicality. It follows that reflectance physicalism *cannot* explain black because it is not a physical color as required by the view. Hence, Premise 4 is validated.

Therefore, we can conclude that reflectance physicalism is false.

6.4 Three Objections

How would reflectance physicalists respond to this argument?

In the literature by color physicalists, especially reflectance physicalists, the reaction to the problem of the color membership of black is somewhat subtle. I failed to find any discussion of black in the paradigmatic color physicalist papers, such as Jackson 1996, 1998, Lewis 1997, Byrne and Hilbert 2003, 2021.[15] However, their silence does not imply that no responses are possible. In the following, I will discuss some possible responses.

To start with, it is impossible to reject Premises 1 and 2. They are conceptually true. Likewise, it is *almost* impossible to reject Premise 3 for the following three considerations.

First, in the color debate, the thesis that black is a color is made explicit by many color objectivists. For instance, McLaughlin claims, "I'll frame my basic proposal for a specific colour, red. But my account is intended to hold for all colours, chromatic and achromatic (white, black, and shades of grey)" (2003: 100).[16]By contrast, if reflectance physicalists reject Premise 3 this would significantly undermine their view.

Besides, the above discussions for Premise 3 make it extremely hard to reject. Consider the point that "Black is a color" is a conventional truth, in Premise 3. One alleged merit of reflectance physicalism is that it takes the related conventions seriously. For instance, in his paper, Lewis argues for reflectance physicalism opening with the sentence: "An adequate theory of colour must be both materialistic and commonsensical" (1997: 325), and his argument relies on the truth of folk psychophysics, which is distilled by analyzing conventional language. For this reason, even if a conventional truth can turn out to be false and potentially subject to elimination or revision by further theoretical considerations, it remains a significant cost for reflectance physicalists to eliminate or revise the conventional truth that black is a color.

Furthermore, consider epistemological role of color experiences, one can ask: what epistemological role of a color experience is more basic than that it invites the belief that a certain chromatic or achromatic visual patch is a color? This epistemological role applies not

[15] Lewis may be an exception. Lewis' paper on color, "Naming the Colours" (1997), says nothing about black. But in his paper "Void and Object" (2004), Lewis gives a counterfactual analysis of "void" and "vacuum", which can be developed into a counterfactual analysis of black. We can conceive how Lewis, were he faced with the problem of black, would respond. I will discuss the point later in this section.

[16] See also Allen 2016, especially Chapter 6.

only to color experiences with ordinary objects, but also to hallucinatory color experiences, blue experiences with sky, after-image colors, mirror colors, etc. This is well captured by Price's skeptical strategy:

> When I see a tomato there is much that I can doubt. I can doubt whether it is a tomato that I am seeing, and not a cleverly painted piece of wax. I can doubt whether there is a material thing there at all. Perhaps what I took for a tomato was really a reflection; perhaps I am even the victim of some hallucination. One thing however I cannot doubt: that there exists a red patch of a round and somewhat bulgy shape, standing out from a background of other colour patches, and having a certain visual depth, and that this whole field of colour is directly present to my consciousness … that something is red and round then and there I cannot doubt … that it now exists, and that I am conscious of it—by me at least who am conscious of it this cannot possibly be doubted. (1932: 3)

This epistemological role of color experiences applies also to black experience, suggesting that the belief that black is a color cannot possibly be doubted.

Hence, it is almost impossible for reflectance physicalists to reject Premise 3. The only option seems to reject Premise 4.

How to reject Premise 4? How can reflectance physicalism explain the nature of black? I will respond to three possible objections to Premise 4.

The first objection: Contrary to Premise 4, there is a clear definition of black in reflectance physicalism: black is an SSR that is zero (or nearly zero). According to reflectance physicalism, non-black colors are SSRs with positive values. It is very natural and conceptually coherent to generalize this definition to black: black is an SSR whose value is zero. This means that there is (almost) no reflected light under any illumination conditions whatsoever. Thus, Premise 4 is false.

Response: Although an SSR with zero value is meaningful in spectrophotometry, this objection fails.[17] This definition of black conflicts with the necessary condition for colors' physicality. As discussed, a color is a physical color only if it is a property that can fulfill the causal role of producing the related color experiences. An SSR with zero value means that there is no reflected light in the causal process underlying black experience, which entails that

[17] Note that I am not questioning SSRs as posited by spectrophotometry. Physicists never identify SSRs with colors. What I am questioning are SSRs as the definition of colors posited by reflectance physicalists, particularly in the case of black.

there is no physical property that can fulfill the causal role producing the related black experiences. It follows that an SSR with zero value is not a physical color. The above definition of black fails.

The second objection: Premise 4 cannot be validated because it is wrong to assume the correlation between the absence of a causal process and the presence of a black experience. Black experiences do not exist. One relatum in the correlation should be the *absence* of a visual experience rather than the presence of a *black experience*. For instance, when one has a visual experience with a Vantablack object, one does not have any visual experience in the related visual region at all. It follows that Premise 4 cannot be established.

Response: This objection fails. It is phenomenologically adequate to assume that black experiences *do* exist. In the case of a Vantablack object or a total solar eclipse, any person with normal vision will have a black experience. Moreover, the way one has these black experiences seems exactly the same as in all other color experiences. For instance, in the case of Vantablack depicted in Figure 6.1, the white appearance of the aluminium foil and the black appearance of the Vantablack object are both visually presented. It is appropriate to claim that a black experience, as a visual experience, is a case of seeing rather than being an absence of seeing.[18]

Besides, there is one more example that vividly shows the presence of a black experience without an underlying causal process. I encourage readers to check this by themselves with the following steps: (i) Open your left eye while closing your right eye with your right hand, covering it firmly to make sure that no light enters your right eye. (ii) Close your left eye suddenly and pay attention what manifests in the visual experience of your right eye. My experience is that when I suddenly close my left eye, I am fully aware of the presence of a black experience via my right eye. I believe that others will have a similar experience. In this example, the mere presence of a black experience is sufficient to assert its reality without the need to assume an underlying causal process.

The third objection to Premise 4: Premise 4 is false because black can be successfully accounted for by a counterfactual analysis of causation according to which black is a color because the absence of a causal process can still be a cause. The definition that black is an SSR of value zero still holds. The crucial idea of the objection is that the absence of a causal

[18] This claim is open to the interpretation that black experiences are visual experiences of absence, where the "absence" is concretized as a part of visual experience. This interpretation is still distinct from the view that black experiences are absences of any visual experience.

process causes the presence of a black experience iff, had there been a reflection of visible light, it would have caused a non-black color experience.

However, given the complexities of applying the counterfactual analysis of causation to black, much work is needed to support this objection. Lewis' (1973) counterfactual analysis of causation and his view (2004) on void and vacuum will be used to substantiate it.[19] I will clarify the fully developed objection in three steps: Step 1 introduces Lewis' analysis of absences; Step 2 is about Lewis' account of causation as applied to absences; Step 3 generalizes Lewis' analysis to black.

Step 1: Lewis claims that there are two kinds of absence, namely, vacuums and voids. He draws the distinction carefully. Roughly, a *void* is the absolute absence of all things. By contrast, a *vacuum* is only almost void: "A vacuum, or an almost-void that still contains flat, inert spacetime … A void, being the absence of any objects at all, is just the most extreme case of an absence" (2004: 281). Moreover, to explain which notion of absence is supposed to be the focus of an account of causation, Lewis lists four notions of absence and endorses the last one, (4), explicitly:

> (1) We could deny, in the face of compelling examples to the contrary, that absences ever cause anything. … (2) We could reify absences non-reductively. A void, so we might say, is a sui generis entity, but it is none the worse for that. … (3) We could reify absences reductively. … For instance, we could identify a hole with the hole-lining that, as we'd normally say, immediately surrounds the hole. (4) The best response is to concede that a void is nothing at all, and that a lesser absence is nothing relevant at all and therefore cannot furnish causal relata. Yet absences can be causes and effects. So I insist … that causation cannot always be the bearing of a causal relation. (2004: 282)

One underlying assumption of (4) is that causation, understood as the relation between cause and effect, is not necessarily a *causal relation*. As a salient case, a void or a vacuum can be a cause and an effect, but it cannot be a causal relatum.

The context of the above discussion is that absences raise a problem for any analysis of causation: given that an analysis of causation needs to account for the relation between cause and effect, how could it deal with the problem of the missing relatum in the case of an absence, such as a void?

[19] Note that Lewis' paper on color, "Naming the Colours" (1997), says nothing about black. But still, we assume that Lewis' thoughts are overall coherent and our generalization of Lewis' thoughts to the analysis of the case of black is not an interpretation, but a natural consequence of his thoughts.

Lewis states that a counterfactual analysis of causation can escape the problem. “Yes; a counterfactual analysis escapes. … The void causes death to one who is cast into it because if, instead, he had been surrounded by suitable objects, he would not have died” (2004: 282). According to Lewis, a counterfactual dependence is a relation, but not necessarily a causal relation. In the case of an absence, the counterfactual dependence between cause and effect should not be analyzed as an intrinsic causal relation between distinct events.[20] In sum, the notion of causal relation, though important, cannot exhaust our understanding of causation, as is clearly suggested by the case of absences. But what is Lewis’ account of causation? This leads to Step 2.

Step 2: Lewis thinks that out of two compatible accounts of causation, the one relevant for absences in this world is as follows:[21]

> What is causation? As a matter of contingent fact, what is the feature of this world, and of other possible worlds sufficiently like it, on which the truth values of causal ascriptions supervene? — It is biff: the pattern of relatedness of events to one another by the relation that is the actual occupant of the biff role. Biff is literally the basic kind of causation, in this world anyway: the basis on which other varieties of causation supervene. (2004: 287)

“Biff” occupies “a functional role for a relation: an intrinsic relation between distinct events that is typically, but perhaps not invariably, associated with a probabilistic version of counterfactual dependence. Biff is defined to be the occupant of this functional role, if such there be” (2004: 283).

What is, according to this notion of causation, Lewis’ analysis of the case of absence? Lewis writes:[22]

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[20] “Note well that in defending a counterfactual analysis, I am not claiming that all causation consists in a relation of counterfactual dependence between (distinct) events. That theory would not escape the problem of missing relata. A relation of counterfactual dependence is still a relation, a relation still needs relata, and absences still fail to provide the needed relata. The counterfactual analysis escapes the problem because, when the relata go missing, it can do without any causal relation at all” (Lewis 2004: 283).

[21] The one that is irrelevant to our discussion is described as follows: “What is causation? As a matter of analytic necessity, across all possible worlds, what is the unified necessary and sufficient condition for causation? — It is somehow a matter of counterfactual dependence of events (or absences) on other events (or absences)” (Lewis 2004: 287). Lewis further thinks that both accounts of causation are right. “Two different answers to two different questions. They are not in competition. I conjecture that both are right” (2004: 287).

[22] According to this notion, causation is the occupant of the biff role for a relation between two distinct events. The complexity arises arise when it comes to substantiating the relation between the absence and the presence, because in the case of an absence there is no corresponding event. “[C]ausation by absence is not an instance of biff. Nevertheless, it can be described in terms of biff” (2004: 285). Namely, in the case of an absence, even though there is no instance of biff, the absence can still semantically satisfy the role via being described in terms of biff. Logically, there are four kinds of cases regarding the relation between presence and absence: (i) the presence of an event causes the presence of an event, (ii) the absence of an event causes the presence of an event,

> The absence of any event of kind *C* directly causes event *e* iff, had there been an event *c* of kind *C*, *c* would or might have biffed some event *d* incompatible with event *e*. (2004: 284)

The natural reading of "incompatible" here is that event *d* and event *e* cannot be classified as of the same kind.

Why is this notion of causation also relevant for black? Because we are concerned with the case of black in this world. In "Naming the Colours" (1997), Lewis also assumes that colors are features of this world or other possible worlds sufficiently like it: "… red is, as a matter of contingent fact, that reflectance property" (1997: 327).[23]

Step 3: Given Lewis' analysis of the causal role of absences according to the relevant notion of causation, how does this extend to the case of black? The generalization is as follows:

> The absence of any event of reflection of visible light causes an event of the type black experience iff, had there been an event of reflection of visible light, it would caused* an event of the type *non*-black color experience such that this event is incompatible with an event of the type black experience.

"Cause*" means whatever is responsible for the causal work governed by the laws of nature in this world. Specifically, it is the occupant of the functional role for a relation between two distinct events that is typically, but perhaps not invariably, associated with a probabilistic version of counterfactual dependence in this world. Moreover, a black experience is incompatible with a non-black color experience, because they are not of the same kind.

So far, I have presented an analysis of the case of black extended from Lewis' analysis of the causal role of absences according to the relevant counterfactual analysis of causation, which supports the claim that the absence of a causal process can cause a black experience. Hence, reflectance physicalism can explain the nature of black. Thus, Premise 4 is false.

Response: This objection is the strongest one. It has the most charitable reading of my argument: it not only acknowledges the empirically established correlation between the

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(iii) the presence of an event causes the absence of an event and (iv) the absence of an event causes the absence of an event. What is relevant to our discussion is that the absence of an event can cause the presence of an event.

[23] In comparison, Chalmers (2006: 47) assumes that primitive colors play the role of the perfect colors that are not instantiated in this world but in the Edenic world, which is supposed to be a remote metaphysically possible world.

absence of a causal process and the presence of a black experience, a building block of Premise 4, but also allows that the absence of a causal process can, in a certain sense, cause a black experience, which challenges Premise 4. However, this objection still fails.

First, it fails because the above counterfactual analysis cannot actually account for the case of black, as it claims. It is based on the notion of causation applicable to this world, which is given by our (contingent) laws of nature. For example, in the case of Vantablack the related counterfactual analysis is as follows:

> The absence of any reflection of visible light by a Vantablack object causes a black experience iff, had there been a reflection of visible light by the Vantablack object, it would have caused* a non-black color experience, which is incompatible with a black experience obtaining.

However, this analysis is nomologically impossible. In this world, Vantablack reflects almost no visible light in all actual situations. "Vantablack … in all actual situations" implies that there is no essential change of the makeup of Vantablack (where an Vantablack object persists). It cannot be the case that Vantablack somehow starts reflecting visible light in any actual situation. Accordingly, the above counterfactual analysis makes no sense because it assumes that Vantablack could reflect visible light in certain actual situations, which is inherently flawed. Therefore, based on the notion of causation applicable to this world, the analysis cannot account for the case of black. The objection fails.

Second, I will identify two problems of the above counterfactual analysis of black: (i) the incomparability of black with absence, and (ii) the irrelevance of the counterfactual analysis to absences.

For (i), black and absence differ in kind. Consequently, Lewis' counterfactual analysis of absence might not be appliable to black. In the case of a void or a vacuum, nothing or almost nothing is there, while in the case of black there are certain materials. The case of Vantablack shows that the absence of any reflection of visible light is intimately related with Vantablack's absorbing almost all visible light. It is precisely due to our (contingent) laws of nature according to which Vantablack absorbs almost all visible light that it is nomologically impossible that, had there been a reflection of visible light by Vantablack, it would have triggered a non-black color experience.

For (ii), the above counterfactual analysis is arguably irrelevant to absences in the first place. It is based on the decision to not take absences seriously. When discussing whether one can escape the problem of missing relata in the case of absences, Lewis mentions, "[a]bsences are spooky things, and we'd do best not to take them seriously. But absences of absences are no problem" (2004: 383). Here, "we'd do best not to take them seriously" can be interpreted as follows. If absences are taken seriously, solving the problem of the missing relata may be impossible and theoretically unproductive. If *not*, there is at least a hope to develop a counterfactual analysis that can escape the same problem. Hence, for being theoretically fruitful, the reasonable choice is not to take absences seriously. In my view, given that to explain absences is obligatory for any account of causation, Lewis' suggestion is that one should find the best way to beg the question, and his counterfactual analysis exemplifies this. However, the best way of begging the question is still irrelevant to solving or dissolving the question.[24] If absence is not well understood, then it is not even possible to make sense of the claim that "absences of absences are no problem", let alone considering whether a counterfactual analysis is superior to other causal analyses.

So far, I have discussed three objections to Premise 4. None of them are successful. Is there any other option for reflectance physicalists? The last resort might be this: to bite the bullet and reject Premise 3 or Premise 1.[25]

To reject Premise 3 is to not acknowledge black as a color, which is to deny the conventional truth that black is a color.

There is room for reflectance physicalists to make such a move. But it will turn out that this move is impossible. Regarding the concern from the conventional truth that black is a color, there is in principle a gap between being conventionally true and being true simpliciter. It might be the case that the conventional truth that black is a color is subject to revision due to further theoretical considerations. When it comes to the revision of the conventional truth, Lewis' own view might hold out hope for reflectance physicalists: "There is no sharp line between sacrosanct intuition and freewheeling theory. … Any revision of previous opinions counts as some cost. But some of our opinions are firmer and less negotiable than others. And some are more naïve and less theoretical than others. And there seems to be some tendency for the more theoretical ones to be more negotiable" (1986: 240–241). However, it is unclear if the conventional truth that black is a color can be revised merely based on this general consideration. If so, similar revisions could also apply to other colors. This consequence does not support reflectance physicalism.

[24] The problem is that to employ a biconditional claim to hypothesize a sufficient and necessary condition for the thesis that the absence of an event can cause the presence of an event without really considering whether or not "the absence of an event" can be clarified by a counterfactual analysis in the first place.

[25] It is impossible for reflectance physicalists to reject Premise 2, that reflectance physicalism is a color theory.

Hence, it is impossible to reject Premise 3.

What about Premise 1? Rejecting Premise 1 means to consider reflectance physicalism as a color theory that is not about *all* colors.[26] This move is absurd. How could a color theory not be about all colors? Actually, the absurdity is inherent in reflectance physicalism. It is primarily motivated by the color phenomena of ordinary non-black objects. Its phenomenology does not concern black phenomena. Recall Byrne and Hilbert's first motivating question for color objectivism: "First, do objects like tomatoes, strawberries, and radishes really have the distinctive property that they appear to have?" (2003: 4). The implied phenomenology is that an object appears to have certain color properties. This phenomenology cannot be applied to the case of black. For instance, in the Vantablack case, the phenomenology is *not* that a Vantablack object appears to have black properties, rather there appears to be a quasi-two-dimensional black appearance or patch.[27] There is no visual phenomenology of an object at all, let alone the visual phenomenology of an object's color appearances. In sum, the motivating question for reflectance physicalism does not address black, so it was never intended to be a color theory also of black.

Back to the main point, is a color theory which cannot explain the nature of black possible? Ordinarily, a color theory must explain all colors. If one insists that black is a special color that deserves a special treatment, then a color theory of non-black colors might be acceptable as a work-in-progress theory. Accordingly, whether or not the argument from the color membership of black is a knock-down objection to reflectance physicalism depends on one's expectation of what a color theory must do. I will leave it as an open question. After all, the falsity of reflectance physicalism does not depend on the full success of one or two arguments, because it has been demonstrated in the previous chapters via several other arguments. The current aim is to look for the specific mistakes in the causal premise of reflectance physicalism, which goal is definitely fulfilled by the argument from the color membership of black.

6.5 The Causal Inefficacy of Reflectances

According to reflectance physicalism, colors are identical to SSRs, certain dispositions to reflect light. One oft-discussed topic in the metaphysics of dispositions is whether dispositional properties can be causally efficacious. Applied to SSRs, this becomes the question whether SSRs are causally efficacious. This section focuses on this question, and it is structured as follows: First, I present three often-mentioned doubts about the causal efficacy

[26] Note that the point is irrelevant to whether reflectance physicalism can successfully account for non-black colors.

[27] Compare this to Version A* as suggested in Section 5.1.

of dispositional properties and then apply them to SSRs. Next, I present Lewis' (1997) account of the causal efficacy of SSRs and conclude that Lewis' account can successfully respond to these doubts. Finally, I will argue that, although successfully dealing with these doubts, Lewis' account inevitably generates a severe problem for reflectance physicalism that leads to the conclusion, merely based on the premises for reflectance physicalism, that the view does not work.

The first often-mentioned doubt arises from questioning the analyticity of the concept of a dispositional property. For instance, "being fragile" means the disposition to break when hit properly. Accordingly, an object's having the property of being fragile conceptually necessitates the object's breaking when hit properly. The conceptual necessitation is merely semantic rather than metaphysical, which is relevant neither to causation nor to a causal explanation of the connection between the property of being fragile and the behavior of breaking. Ergo, one might claim that dispositional properties are causally inefficacious.[28] The same can be said about SSRs.

The second doubt arises from the linguistic observation of how the phrase "because" is used in a certain context.[29] For instance, the following sentence seems meaningful:

"The vase is smashed and breaks, because it is fragile."

One might consider the "because" sentence as a causal explanation: the property of being fragile of the vase causally explains that the vase breaks when smashed. However, if being fragile is identical with the disposition to break when smashed, as suggested by dispositionalists, it cannot be a causal explanation. Because an identical relation between the two precludes a causal relation. Therefore, the above "because" sentence cannot be a causal explanation. Ergo, one might claim that dispositional properties are causally inefficacious.[30] The same concern applies to SSRs.

The third doubt bears on the problem of causal overdetermination. For instance, Jackson argues against the causal efficacy of dispositional properties as follows:

[28] This line of thought is developed by many philosophers: Armstrong (1968), Mackie (1973, 1977), Block (1990) and McKitrick (2004, 2005).
[29] The point is discussed by Jochen Briesen (2020: Ch. 5).
[30] The proper reading of the "because"-sentence might be expressivist. According to expressivism, what "because" primarily indicates is that the belief expressed by "The vase is smashed and becomes fragile" is epistemically grounded in the belief expressed by "it is fragile". The "grounding/basing relation" in an epistemic sense is expounded and defended by Freitag (2024).

> Consider a fragile glass that shatters on being dropped because it is fragile, and not (say) because of some peculiarity in the way it is dropped. Suppose that it is a certain kind of bonding *B* between the glass molecules that make up the glass which is responsible for the glass being such that if dropped it breaks. Then the dispositional property of being fragile is the second order property of having some first order property or other, bonding *B* as we are supposing, that is responsible for the glass being such as to break when dropped. And the first order property, bonding *B*, is the categorical basis of the fragility. But then it is bonding *B* together with the dropping that causes the breaking; there is nothing left for the second order property, the disposition itself, to do. All the causal work is done by bonding *B* together with the dropping. To admit the fragility also as a cause of the breaking would be to admit a curious and ontologically extravagant kind of overdetermination. (1996: 202)[31]

Applied to SSRs, the doubt is that if the causal work can be done by the categorical basis of SSRs to reflect light alone, then there is no need to assume that SSRs are causes too. To assume that SSRs are causally efficacious would lead to the problem of causal overdetermination.

If these doubts cannot be well answered then reflectance physicalism is faced with serious consequences. In the color debate, the causal efficacy of SSRs is supposed to be an advantage of reflectance physicalism over some other color theories.[32] If the doubts are valid, this advantage disappears. Moreover, if the doubts are valid, reflectance physicalism ends up with an internal inconsistency. Namely, if SSRs are causally inefficacious, then the identity thesis of reflectance physicalism violates the causal premise of the view, according to which colors must be identified with physical colors that are causally efficacious in the causal process underlying color perceptions.

Hence, reflectance physicalists must respond to these doubts. But they do not have to respond to all three doubts. I take Jackson's doubt, the problem of causal overdetermination, to be the strongest one, which calls directly for a detailed account by reflectance physicalists

[31] The aim of Jackson's paper is to argue for microstructure physicalism about colors, and to argue against color dispositionalism, according to which colors are dispositions to look colored under certain conditions. His argument is based on the causal premise, viz., that colors are normal causes of looking colored, and on the thesis that causes must be categorical properties of objects rather than dispositional ones. Thus, Jackson's argument is directed not only against color dispositionalism, but also against reflectance physicalism, which identifies colors with SSRs that are dispositions.

[32] For instance, one objection to color primitivism is that primitive colors are arguably causally inefficacious. Thus, a color primitivist is always obligated to defend the thesis that primitive colors are causal efficacious (see Allen 2016: Ch. 5). There is no such objection to reflectance physicalism if SSRs are causally efficacious.

of the causal efficacy of SSRs. If such an account can be given, there is no need to respond to the first two doubts. There are many ways for reflectance physicalists to dispel these doubts, as long as the third doubt is successfully answered. For instance, one can emphasize that, if the causal efficacy of SSRs is established independently of the conceptual and linguistic points, any doubts based on these points are simply irrelevant.[33, 34] For this reason, I will only discuss Jackson's doubt.

Among reflectance physicalists, Byrne and Hilbert (2003, 2021) do not respond to Jackson's doubt, because "it would take us too far into metaphysics" (2003: 20, fn. 25). But Lewis (1997) gives an account of the causal efficacy of SSRs, according to which the overdetermination problem can be dissolved. Thus, we take his account as a representative response:

> [W]e should not have been talking about properties as causes in the first place. That is loose talk. … Really, the causing is done by particular havings of properties – particular 'events', as we call them. … The very same event that is essentially a having of some causal basis of a certain disposition is also accidentally a having of the disposition itself. So an effect of this event is caused by a having of the basis, and caused also by a having of the disposition. But since these havings are one and the same event, there is no redundant causation. So a colour experience may be caused by a colour, and also by the micro-structural causal basis of the reflectance values that comprise that colour, without having a case of causal overdetermination. (1997: 331)

According to Lewis, particular events are genuine causes. An event that is a having of some causal basis of a disposition is one and the same event as having that disposition. Thus, in an event, both (the having of) the causal basis of a disposition and (the having of) the disposition are causes, because they are two aspects of the event that is the genuine cause. Accordingly, "an SSR causes a color experience" means that the color experience is caused by an event

[33] Under the assumption that SSRs are causally efficacious, this is not to deny that metaphysical doubts drawn from the conceptual or the linguistic concern are plausible; these are still useful ways of suggesting some metaphysical conclusions, especially at the initial stage of the investigation. However, if the metaphysics of the causal efficacy of SSRs can be established in a way that is independent of the conceptual and the linguistic concern, a believer in the causal efficacy of SSRs can suspend these concerns and leave them as conceptual or linguistic issues.

[34] Another way to dispel the conceptual and linguistic doubts is to appeal to the general thesis that the metaphysics of a domain is explanatorily prior to its conceptual analysis or linguistic representation. This point presupposes that, when investigating the causal efficacy of dispositions, a metaphysics-first strategy is preferable to an epistemology-(or semantics-)first strategy. This can easily be accepted by many realists, including reflectance physicalists. For some general discussion, see Peacocke 2019 for the defense of a metaphysics-first strategy and see Dummett 1991 for the defense of a semantics-first strategy.

that is a having of both the SSR and its microstructural causal basis. Thus, there is no problem of causal overdetermination.

Is this a successful response? I think so. The problem is not solved but dissolved. If one holds the view that the fundamental entities in causation are not events but *properties*, and that the candidate properties must be categorical and non-dispositional, like Jackson does, then it follows that only microphysical properties are causes, which leads to the problem of causal overdetermination. However, if one holds the view that the fundamental entities in causation are *events* rather than the properties instantiated in the events, like Lewis does, then there is no problem of causal overdetermination at all.[35] In sum, Lewis' account can clearly explain away the problem.

For the moment, the verdict seems to be that, given Lewis' account, we need not worry anymore about the causal efficacy of SSRs. However, as I will show in the remainder of this section, Lewis' account engenders one severe problem for reflectance physicalism.

The problem is that, in reflectance physicalists' attempt to identify colors with SSRs, there is a difficulty of singling out SSRs from many other properties co-instantiated in the same cause-event. Call it the *problem of individuation*. More precisely, in the event that an object reflects light, there are many co-instantiated properties, including: microstructural properties, SSRs, the triple of integrals of reflectance over the three intervals of the visible spectrum, the disposition to look a certain color to certain perceivers, etc.[36] According to Lewis' account, all of these properties are causes in the sense that they are properties instantiated in the same event that is the genuine cause. However, given that all of these co-instantiated properties are causes in this sense, there is naturally the problem of individuation, which can be formulated in three questions: What are the decisive reasons for reflectance physicalists to identify colors with SSRs rather than (i) microstructural properties, (ii) triple-reflectance properties,[37] or (iii) the dispositions to look a certain color to certain perceivers?

Despite the similarities, the above three questions point in three quite different directions. Question (i) pertains to the debate between reflectance physicalism and microstructure

[35] Philosophers like Jackson, who hold the view that the fundamental entities in causation are properties, might still have a view about causal relations between events. For instance, one such view is that a causal relation between events holds in virtue of the causal relation between the categorical properties in these events. On this view, there are two aspects of a causal relation: a causal relation between events and one between categorical properties, in which the former holds in virtue of the latter. Events are still less fundamental than properties. This view of the causal relation between events has to be distinguished from Lewis' view (see Jackson 1996: 201).

[36] The triple of integrals of reflectance over the three intervals of the visible spectrum is the property posited on the grounds that the normal human visual system is not uniformly sensitive to the whole visible spectrum, rather, it is only sensitive to three intervals of the visible spectrum, the long-wave, the middle-wave and the short-wave interval.

[37] Triple-reflectance properties mean the reflectance properties of the triple of integrals of reflectance over the three intervals of the visible spectrum.

physicalism: reflectance physicalists need to explain why SSRs, as opposed to microstructural properties, are the superior candidates for physical colors. Question (ii) concerns an internal problem among reflectance physicalists: reflectance physicalists like Byrne and Hilbert need to explain why SSRs are better colors than triple-reflectance properties. Question (iii) addresses the problem of how to differentiate reflectance physicalism from color dispositionalism: reflectance physicalists need to explain why SSRs are better candidates than color dispositions.

In view of the problem of individuation, if no reason for singling out the SSRs from the other co-instantiated properties in the same cause-event can be provided, reflectance physicalism cannot even be established. Do reflectance physicalists have the required reason? After all, Lewis' account of the causal efficacy of SSRs just supplements the causal premise. If there are other premises that can indeed single out the SSRs from the other co-instantiated properties in the same cause-event, then there is no problem of individuation. In what follows, I will set aside questions (i) and (ii) and focus only on (iii).[38] I will argue for a somewhat surprising conclusion associated with (iii): all premises of reflectance physicalism can accommodate color dispositionalism. Namely, I will show that no premise of reflectance physicalism can explain why SSRs are superior as color candidates to color dispositions. Accordingly, reflectance physicalism cannot even be established because color dispositionalism cannot be ruled out.

What are reflectance physicalists' reasons for identifying colors with SSRs rather than with dispositions to look a certain color to certain perceivers? Or, what are main factors thereof that exclude color dispositionalism? Byrne and Hilbert's and Lewis' premises for reflectance physicalism will be examined in turn.

An examination of Byrne and Hilbert's premises shows that none of the premises excludes color dispositionalism. As indicated, given Lewis' account of the causal efficacy of SSR, color dispositionalism cannot be excluded by the causal premise. Color dispositionalism also fits the phenomenological premise well, which requires that "the relevant physical property must be a property of objects (more strictly, surfaces)" (2003: 9), because color dispositionalists can claim that dispositions to look colored are just physical properties of objects' surfaces. With regard to representationalism, "we therefore need a physical property of objects that is largely illumination-independent – a physical property that an object can retain through changes in illumination" (2003: 9), color dispositionalism still stands.

[38] Note that (i) will be the topic of Section 7.2, because the problem underlying question (i) can be applied to the discussion of microstructure physicalism in Section 7.2. Question (ii) will not be further discussed because it is an internal issue among reflectance physicalists.

According to color dispositionalism, color dispositions are genuine properties constitutively possessed by objects, which are of course illumination-independent. Even though the manifestations of color dispositions are illumination- and perceiver-dependent, the color dispositions themselves are not. Nor does the vision science premise, "[W]e need a property that human visual systems could plausibly recover from the responses of the three kinds of cone photoreceptors", constitute a substantial reason for excluding color dispositionalism. One might argue as follows: A visual experience is identical with or supervenes on the underlying process in the human visual system. Assuming that a visual experience has a representational content in which dispositional properties are attributed to objects, one can claim that, if the alleged recovery process is real, color dispositions can be recovered because they figure in the representational content of the visual experience. Therefore, none of Byrne and Hilbert's premises excludes color dispositionalism.

Lewis' premises cannot exclude color dispositionalism, either. Here they are:

> Drawing on these connecting principles, and also on the part of folk psychophysics that classifies colours as properties (for the most part) of the surfaces of opaque things, and colour experiences as inner states of people (and perhaps other animals), we have folk-psychophysical roles for the colours and for the colour experiences. When we take the theoretical terms to name the occupants of the theoretical roles, we arrive at 'definitions' such as these.
>
> D1 Red is the surface property of things which typically causes experience of red in people who have such things before their eyes.
>
> D2 Experience of red is the inner state of people which is the typical effect of having red things before the eyes.
>
> If, as a matter of contingent fact, the surface property that causes experience of red is a certain reflectance property – that is, a property that supervenes on the thing's reflectance spectrum – then D1 may serve as a premise for a chromophysical identification: red is, as a matter of contingent fact, that reflectance property. And if, as a matter of contingent fact, the inner state which is the typical effect of red things before the eyes is a certain pattern of neuron firings in the visual cortex, then D2 may serve as a premise for a psychophysical identification: experience of red is, as a matter of contingent fact, that pattern of neural firings. (1997: 327)

The main point where Lewis' approach differs from Byrne and Hilbert's is methodological, insofar as Lewis' approach (1997) relies on what he calls "the folk psychophysics of color". The reality of the alleged folk psychophysics is not our focus.[39, 40] The point is that even if it is valid, color dispositionalism still fits well with the definitions given by Lewis. D1 says that colors must be surface properties that cause the related color experience. According to color dispositionalism, color dispositions are just properties of surfaces that dispose the objects to look certain colors in certain circumstances. Thus, color dispositions are surface properties.[41] Moreover, given Lewis' account of the causal efficacy of SSRs, dispositions to look certain colors to certain perceivers are causes in the same sense as SSRs are, because both are dispositional properties co-instantiated in the same event that is the genuine cause. Color dispositions are surface properties that cause the related color experiences. Hence, color dispositionalism satisfies D1.

According to D2, experiences of colors must be the typical effects of having colored things before the eyes. According to color dispositionalism, the manifestations of color dispositions are just the typical effects of having things with the related color before the eyes. Moreover, color dispositionalism is well compatible with the thesis that color experiences can be identified with certain patterns of neural firings, as suggested by Lewis. Hence, color dispositionalism also satisfies D2.

Therefore, none of the premises of reflectance physicalism can explain why SSRs are better color candidates than color dispositions. The problem of individuation in question (iii) cannot be solved. Accordingly, reflectance physicalism cannot be established because color dispositionalism cannot be ruled out.

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[39] The folk psychophysics of color associates "colors" and "color experiences" with certain theoretical roles. Moreover, the folk psychophysics of color involves the existential claim that there are entities that play these roles. Thus, the folk psychophysics of color implicitly defines "colors" and "color experiences" as the names of the occupants of these roles. The definition of color is like D1; the definition of color experience is D2. This way of defining theoretical terms can be traced back to Lewis' paper "How to Define Theoretical Terms" (1970).

[40] It is controversial whether there really is a folk psychophysics of color in Lewis' sense. Even if we assume the existence of such a folk psychophysics, it is still not obvious why Lewis' definition of colors in terms of the properties that cause the related color experiences is the right one, among other tenets in the folk psychophysics of color. It might well be the case that folk psychophysics is incoherent. Johnston 1992 and Martine 2006 contain detailed discussions regarding how some core intuitive beliefs about color that seem to be well supported by ordinary intuition conflict with each other. If one assumes that the folk psychophysics of color is similar to our ordinary beliefs about colors, a similar analysis can be applied to folk psychophysics.

[41] For instance, McDowell, a color dispositionalist, makes the point clear: "No doubt it is true that a given thing is red in virtue of some microscopic textural property of its surface; but a predication understood only in such terms … would not be an ascription of the secondary quality of redness" (1985: 134).

PART II

THE EXTENDED TARGETS OF THE ANTI-OBJECTIVIST VIEW

7

Other Versions of Reflectance-grounded Objectivism

Part I thoroughly examined reflectance physicalism, a typical version of reflectance-grounded objectivism. This chapter examines other versions. It has the following structure: In Section 7.1, microstructure physicalism is discussed and rejected. In Section 7.2, color primitivism is examined and refuted. Section 7.3 clarifies the role of color constancy in the argument for reflectance-grounded objectivism. Specifically, I take Allen's argument from color constancy as a representative. In Section 7.4, Allen's argument is examined, charitably modified and eventually disproved.

7.1 Microstructure Physicalism

Microstructure physicalism is the view that colors are identical with the microstructural properties of objects that are the causal (or categorical) basis of their reflectance properties (Smart 1975; Jackson 1996, 1998). I will discuss Jackson's version as representative of microstructure physicalism.

As hinted in Section 6.5, one advantage of microstructure physicalism is that it can avoid the problem of causal overdetermination. Recall the problem: If the causal work in light reflection by an ordinary object is done only by the causal *basis* of its disposition to reflect light, then there is no need to acknowledge its disposition to reflect light as a cause. How can microstructure physicalism avoid this problem?

As mentioned, according to Jackson's view of causation, the fundamental entities in causation are not events but properties, and the candidate properties must be categorical and non-dispositional. It follows that microstructural properties are the only causes of light reflection.[1] There is thus no causal overdetermination. Moreover, due to this neat response, microstructure physicalism has no subsequent difficulties, while reflectance physicalism faces many. As discussed, Lewis' response to the problem of causal overdetermination leads to the problem of individuation, which entails that reflectance physicalism does not follow from by its premises. Put another way, when faced with the problem of causal overdetermination, the metaphysical view of causation underlying microstructure physicalism makes it superior to reflectance physicalism.

[1] See Section 6.5.

However, is microstructure physicalism a plausible view in the first place? The answer is no. The primary reason is that the view still relies on the SSR Thesis and the falsity of the latter entails the falsity of the former. Thus, the examination of microstructure physicalism will be structurally similar to that of reflectance physicalism. Namely, we can infer that microstructure physicalism is false before looking for the specific errors of the view. The section is structured as follows: Section 7.1.1 argues that microstructure physicalism is false because of the falsity of the SSR Thesis, and Section 7.1.2 focuses on one specific problem of the view: the metamerism problem.

7.1.1 Corollary of the Falsity of the SSR Thesis

I propose that microstructure physicalism is false because it is based on the SSR Thesis, which is false. The SSR Thesis is refuted in Chapter 3. The remaining question is: Does microstructure physicalism indeed include the SSR Thesis?

Yes, the SSR Thesis is given by microstructure physicalism and its underlying metaphysics of dispositions. First, according to microstructure physicalism, SSRs have categorical or causal bases that are intrinsic microstructural properties of material objects. Second, according to microstructure physicalists' metaphysics of dispositions, a disposition has a categorical or causal basis only if the disposition is intrinsic. A disposition is "intrinsic" to an object only if the object has the disposition regardless of any external factors.[2] Combining the two points, it follows that SSRs are intrinsic dispositional properties of material objects, which is exactly the SSR Thesis.

Note that the intrinsicality of (either colors or reflectance) dispositions is not made explicit but still implied by microstructure physicalists. For instance, Jackson claims that "[w]e are accepting the familiar point that – with the possible exception of bare dispositions – to have a disposition is to have a relatively intrinsic nature in virtue of which some subjunctive conditional is true" (1996: 208). If a disposition of an object is not intrinsic to that object, then it makes no sense to claim that "to have a disposition is to have a relatively intrinsic nature in virtue of which …". For instance, if a disposition is constituted by a relation between an object and other objects, then it makes no sense to claim that for an object "to have a disposition is to have a relatively intrinsic nature in virtue of which …". Rather, the proper claim would be that for an object to have the disposition is for it to have a relational property in virtue of which the object stands in the relation with the other objects.

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[2] See McKitrick 2003 for a discussion of the distinction between intrinsic and extrinsic properties.

Therefore, microstructure physicalism is indeed based on the SSR Thesis. We can conclude that microstructure physicalism is false.

7.1.2 The Metamerism Problem

This section focuses on one specific problem of microstructure physicalism: the metamerism problem. Note that the following analysis does not rely on any additional (metaphysical, epistemological or semantic) assumptions. All that is required is to pay attention to a certain color phenomenon: metamerism. Let me emphasize that metamerism is also a problem for reflectance physicalism.

Metamerism is characterized as follows: under certain illumination conditions, some objects that have different SSRs exhibit indistinguishable color appearances to the same perceiver (and under slightly different illumination conditions these objects can have *different* color appearances to the same perceiver). For instance, Byrne and Hilbert's characterization is that "objects with quite different reflectances can match in color under a given illuminant" (2003: 10). Formally put, in a metamerism regarding *n* objects with *n* SSRs under the same illumination conditions, the same color appearance correlates to *n* SSRs under the same illumination. Call this the ordinary version of metamerism.

Metamerism is due to the fact that there are three classes of cone cells in the human visual system which are sensitive to three different but overlapping intervals of wavelengths in the visible spectrum (see Figure 7.1). It indicates a more general understanding of metamerism: for objects with different SSRs, if the reflected spectral powers from the objects are the same for the parts that enter the visual system, then due to the overall effect of the respective sensitivities of the classes of cone cells these objects have indistinguishable color appearances. Based on this general understanding, the "the same illumination" in the ordinary version of metamerism can be replaced by "different illumination conditions".

Accordingly, one can characterize metamerism as follows: in a metamerism regarding *n* objects with *n* SSRs under *n* illumination conditions, the same color appearance correlates to *n* SSRs under n illumination conditions. Call this the general version of metamerism.

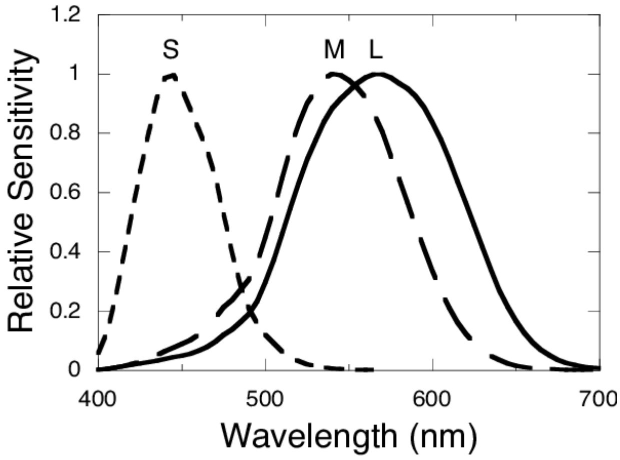

Figure 7.1: The relative spectral sensitivities of the three classes of cone cells.

How can microstructure physicalism account for metamerism? In the remainder of this section, I will show that microstructure physicalism can account neither for the general nor for the ordinary version of metamerism. More specifically, the general version falsifies microstructure physicalism, while the ordinary version suggests some mistakes of the view.

First, microstructure physicalism cannot account for the general version of metamerism: According to the general version, the same color appearance correlates to *n* different SSRs under *n* different illumination conditions. In this version, the correlation is ternary, not binary. Namely, there is no binary correlation between color appearances and SSRs, but a ternary correlation among color appearances, SSRs and illumination conditions. As a consequence, there is no binary correlation between color appearances and the categorical bases of SSRs. Microstructure physicalism cannot account for the general version of metamerism, for the principled reason that it can only account for a binary correlation between SSRs and color appearances. This is made explicit in Jackson's statement about red as an example: "We can work with the rough schema: redness is the property of objects which typically causes them to look red in the right way, where the phrase 'the right way' is simply code for whatever is needed to bring causation up to presentation, for whatever is needed to make the right selection from the very many normal causes of a thing's looking red" (1996: 201). The schema is based on the assumption that there exists a "right way" to select the right cause out of many options such that the red-property of objects causes red-experiences. However, the assumption hinges on the preconception that, in the case of light reflection, the empirical correlation is a binary relation between the properties of objects and color appearances (or experiences), while illumination is presumably included in "the right way" of selecting this binary relation.

According to the general version of metamerism, where the correlation is ternary, such ternary relation cannot in principle be accounted for by this preconception.

The reason the schema fails to account for the general version of metamerism is that microstructure physicalism is based on the SSR Thesis, according to which SSRs are illumination-independent. Consequently, when faced with the general version of metamerism, where illumination is an indispensable relatum in the correlation, there is no way for microstructure physicalists to bring back illumination into their theory. Hence, the general version of metamerism falsifies microstructure physicalism.

Second, even if we only assume the ordinary version of metamerism, microstructure physicalism still cannot explain metamerism. Note that in the literature the metamerism problem is always discussed under this simpler assumption.[3]

Nevertheless, there is an initial hope. The ordinary version of metamerism is that the same color experience correlates to *n* different SSRs under the same illumination conditions. Accordingly, one might reason as follows: given that the illumination conditions remain the same, they can be excluded in the characterization of the correlation, which results in a binary correlation between SSRs and color appearances. This correlation fits well with the schema of microstructure physicalism, which can neatly interpret the binary correlation between SSRs and color appearances as a causal relation between the categorical bases of SSRs and color appearances.

Despite this initial plausibility, a severe problem remains. The correlation between color appearances and SSRs, though binary, is a one-to-many relation. Consequently, microstructure physicalists have to modify their view to account for this. The possible options in the literature are to treat color properties as disjunctions of microstructures, types of microstructures, determinable properties of having different determinate microstructures and higher-order properties of having different microstructures.[4] As I will show, whatever the choice, the modified view still conflicts with the basic schema of microstructure physicalism. The argument is as follows:

Premise 1: If microstructure physicalism is true, colors are causal properties.

Premise 2: A causal property is a concrete property.

[3] See Byrne and Hilbert 2003, Allen 2016 and Laura 2017. Jackson (1996) does not mention the metamerism problem. But he is aware of the problem of the one-to-many relation suggested by the metamerism problem. "What is controversial is what is sufficient for *E* to be the presentation of *P*. We know that mere causal connection is not enough: there are far too many normal causes of any given experience" (1996: 201).

[4] Among microstructure physicalists, Smart (1975) holds the view that colors are disjunctive properties. Among reflectance physicalists, Byrne and Hilbert (2003) hold the view that colors are types.

Sub-conclusion: If microstructure physicalism is true, colors are concrete properties.

Premise 3: If microstructure physicalism is true, colors are either disjunctive properties or types or determinable properties or higher-order properties.

Premise 4: It is not the case that disjunctive properties, types, determinable properties or higher-order properties are concrete properties.

Conclusion: Microstructure physicalism is false.

The argument is valid. We examine its soundness. Premise 1 is given by the basic schema of microstructure physicalism. Premise 2 is empirically true. It is an empirical fact that specific causal processes are concrete. Thus the causal properties that are responsible for specific causal processes must be concrete properties. Combining Premises 1 and 2, the Sub-conclusion follows: if microstructure physicalism is true, colors are concrete properties. Premise 3 is based on microstructure physicalism as modified in response to the challenge from the above-mentioned problem. Premise 4 is conceptually true. Disjunctive properties, types, determinable properties and higher-order properties are abstract rather than concrete.[5] Hence we arrive at the conclusion that microstructure physicalism is false.

The upshot of the argument is that the basic schema of microstructure physicalism cannot account for the one-to-many correlation between color appearances and multiple microstructures. To account for it, a minimal abstraction from a concrete property must be involved, which conflicts with the thesis that causal properties must be concrete, which is an empirical fact.

Again, the game of modifications can go on.[6] However, there is no need for us to take part in the game. First, whatever the technical maneuver involved in a modification might be, it is a still response based on the simpler assumption that only the ordinary version of metamerism needs to be accounted for. Microstructure physicalism is in principle unable to account for the general version of metamerism. Second, discussing the ordinary version of metamerism only served to find the internal mistakes of the view, which has been achieved. Third, since we have demonstrated in Section 7.1.1 that the view is false for independent reasons, whatever the response might be, it cannot prove the truth of microstructure physicalism.

[5] In comparison, the disjunct properties, tokens, determinate properties or first-order properties involved in a causal process are concrete. “First-order property” means a property pertaining directly to an individual or object rather than to another property.

[6] For instance, a microstructure physicalist can further modify the view such that, despite the abstraction from concrete properties, such abstract properties are causal because they are responsible for the instantiation of concrete causal properties in specific causal processes. Thus, Premise 2 would not be established.

7.2 Color Primitivism

Color primitivism is the view that colors are sui generis, non-reducible, illumination-independent, mind-independent intrinsic properties of physical objects (ordinary material objects, illuminants, translucent objects, etc.). For instance, the redness of an apple is a sui generis intrinsic property of it, independent of any external factors such as illumination conditions or the presence of an observer. In the color debate, primitivism is an influential position with increasing popularity. Various versions of primitivism have been defended by Campbell (1993, 2005, 2006, 2021), Stroud (2000), Watkins (2010), Gert (2008, 2017, 2021) and Allen (2011, 2015, 2016). It is worth emphasizing some of its merits.

First, primitivism fits well with the pre-theoretical, commonsensical belief that there is a mind-independent world populated with colored objects such as green leaves, red apples, white snow, etc.[7] For instance, when having the visual experience of an apple in daylight, one intuitively believes that the apple is red at all times, regardless of gaps in observation due to blinking eyes or momentarily looking away.

Second, primitivism captures the instantiation phenomenology of color. For instance, when having the visual experience of an apple, it is natural to characterize its phenomenology by "The apple looks/appears/seems to be red". The redness presented in one's experience seems to be an intrinsic property instantiated by the apple. Primitivism aligns with this instantiation phenomenology of color.

Third, primitivism is a theoretically simple view. Unlike many other views, it gets by without appealing to more complicated theoretical constructs, such as identity theses, biconditional claims or functionalist analyses. Instead, it aims to highlight that the nature of color cannot be captured by these theoretical frameworks.

Fourth, primitivism plays a crucial role in some other color theories. One approach develops primitivism as eliminativism. More specifically, primitivism is first construed as the negation of color reductionism. If the former is favored over the latter, then there is a further choice between realist and eliminativist primitivism. Some philosophers hold the view that eliminativist primitivism is the best account for primitivism.[8] Accordingly, primitivism is a form of eliminativism. In another approach, primitivism serves as a crucial part of a hybrid view of color. For instance, Chalmers (2006) develops a hybrid view of color with the method

[7] Here, I assume that there *is* an intuitive belief that colors are mind-independent. However, some philosophers argue that it is difficult to give a coherent account of our pre-theoretical intuitive beliefs about color. See Johnston 1992 and Martine 2006 for discussions regarding how some intuitive beliefs about color can conflict with each other.

[8] For a version of eliminativist primitivism, see Pautz 2006a. According to this view, colors are only apparent sui generis properties as of objects.

of role analysis. On this view, color ontology is fixed by an analysis of the roles that we want colors to play. Specifically, primitive colors play the role of being perfect colors, which are however not instantiated in this world but only in the Edenic world, which is a metaphysically possible world.[9]

Despite these merits, is primitivism plausible in the first place? The answer is no. As will become clear, primitivism is based on the SSR Thesis. The SSR Thesis is false, as we saw in Chapter 3. It follows that we can conclude that primitivism is false even before scrutinizing specific errors in the argument for the thesis.

In the following, I will take Allen's (2016) view as a representative of color primitivism.[10] A similar analysis applies to other versions of primitivism. Subsection 7.2.1 presents Allen's primitivism. Subsection 7.2.2 pertains to the corollary of the falsity of the SSR Thesis, due to which primitivism is false.

Note that, as mentioned in Section 1.5 and Chapter 5, Allen's *argument from color constancy* supports all main versions of reflectance-grounded objectivism, including primitivism. Therefore, I will address the argument in the broader context of reflectance-grounded objectivism, not just primitivism. Specifically, in Section 7.3, I present the argument, and in Section 7.4, I disproves it.

7.2.1 Allen's Primitivism

Allen's primitivism is the conjunction of two theses:[11]

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[9] In comparison, physical colors play the role of being the imperfect colors of this world. Imperfect colors stand in the matching-relation to perfect colors. "On the two-stage view, the natural candidates to be called 'colors' are perfect colors and imperfect colors. Both of these can be seen as playing one crucial role associated with colors: they are properties attributed in color experiences. Perfect colors are attributed in Edenic contents, and imperfect colors are attributed in ordinary contents. Perfect colors play certain further core roles that imperfect colors do not: we seem to be acquainted with their intrinsic nature in color experience, and the perfect colors arguably stand in relevant intrinsic structural relations to each other in a way that imperfect colors do not" (Chalmers 2006: 47).

[10] The reason for choosing Allen's version is that his view is more closely related to color phenomena, which, I think, is the natural starting point for doing color investigations. More specifically, Allen attempts to distill a mind-independence notion of color based on his formulation of color constancy phenomena. This does not mean that other versions of primitivism are unimportant. For instance, Gert's (2017) recent defense is developed within the framework of neo-pragmatism in philosophy of language, particularly emphasizing the implausibility of color reductionism in the sense that "the central truths about color do not need to be explained in terms of anything outside of the domain of color … the reason why we cannot explain these central truths in a reductive way is that, ontologically, colors are primitive" (2017: 12). Yet, we still take Allen's version of primitivism to be more representative, since we assume that colors are more closely related to color phenomena rather than to color language. Importantly, our objection to primitivism is not influenced by the choice of the specific version.

[11] Besides these two theses, Allen also assumes a naïve realist theory of perception as a background commitment. According to a naïve realist theory of perception, veridical perceptual experiences are relational events. The phenomenal characters of experiences are determined by (or inherited from) mind-independent objects, properties and relations (2016: 14). For defenses of naïve realist theories of perception, see Campbell 2002, 2021, Martin 2002, Fish 2009 and Logue 2012. Allen doesn't give any argument for the view in his 2016 monograph. Somewhere else, Allen (2019) develops a form of *transcendental* naïve realism, according to which the

Mind-Independence: "[C]olors are properties of physical objects, light sources, etc. whose essential nature is constitutively independent of the experiences, and psychological responses more generally, of perceiving subjects" (2016: 16).

Distinctness: "[C]olors are properties of physical objects, light sources, etc. that are distinct from properties identified by the physical sciences" (2016: 74).

Mind-Independence is claimed to best explain *color constancy*, where "the colors of objects are perceived to remain constant throughout variations in the conditions under which they are perceived, and so throughout variations in the way that objects appear as the perceptual conditions vary" (2016: 16). According to Allen, color constancy is a genuine perceptual constancy "in the sense that there is a phenomenologically salient respect in which objects appear the same as perceptual conditions vary" (2016: 29).

Distinctness is established by a modal argument aiming to show that "colours cannot be identical to physical properties of objects because colours and their putative physical reduction bases differ in their modal properties" (2016: 15). As a result, colors are irreducible properties, whose essential natures cannot be fully captured by physical descriptions.

There is a dependence between the two theses: Distinctness entails Mind-Independence. More precisely, only if Mind-Independence (that colors are mind-independent properties of the world) is true can one further investigate whether, among the mind-independent properties, colors are distinct from physical properties. Moreover, one underlying assumption of Distinctness is that colors supervene on reflectance properties (see below).[12] The nature of reflectance properties is given by the SSR Thesis, namely, reflectance properties are intrinsic to objects. Consequently, it is conceptually incoherent to assume that the supervening colors are non-intrinsic to objects. The intrinsicality of supervening colors entails their mind-independence. As a result, Distinctness entails Mind-Independence. If Mind-Independence is false then Distinctness is too. As will be clear, there is no need to discuss Allen's argument for Distinctness, because Mind-Independence cannot be established in the first place.

transcendental attitude to the naïve realist account of perception makes the position in some sense immune to falsification.

[12] This is also made clear in Allen's (2016: Ch. 4) argument for Distinctness.

7.2.2 Corollary of the Falsity of the SSR Thesis

Primitivism is false, because it is based on the SSR Thesis, which is false. The SSR Thesis has been refuted in Chapter 3. The remaining question is: does primitivism include the SSR Thesis?

Yes, it is a sociological fact that color primitivists accept the SSR Thesis as given and included by primitivism. For instance, as Allen sums up, "it is commonly assumed that colours at least supervene on reflectances: that there can be no difference in colour without a difference in reflectance. This might either be because colours are identical with types of reflectance profile (as some physicalists suggest) or because colours are distinct properties that supervene on objects' reflectance profiles (as I will argue in …)" (2016: 53).[13] If the subvenient SSRs are not intrinsic to objects, it cannot be the case that the supervening primitive colors are intrinsic to objects, as suggested by primitivists.[14] Thus, a necessary precondition for making sense of the supervenience of primitive colors on SSRs is that SSRs are intrinsic properties of objects. Accordingly, it is fair to claim that primitivism is based on the SSR Thesis.

Therefore, we can conclude that primitivism is false.

7.3 Color Constancy for Reflectance-grounded Objectivism

This section discusses Allen's argument from color constancy for Mind-Independence. As mentioned, the argument supports reflectance-grounded objectivism.

First, the argument works equally all main versions of reflectance-grounded objectivism, including primitivism. This is because Mind-Independence is not just a thesis of primitivism but also of reflectance-grounded objectivism. As discussed in Section 1.2, thesis (a2) of reflectance-grounded objectivism is that colors are essentially SSR-related intrinsic properties of material objects, which entails Mind-Independence.

Second, the argument focuses on color constancy that is emphasized and similarly formulated by all proponents of reflectance-grounded objectivism. The literature shows that color constancy can support reflectance-grounded objectivism in two ways. The first way is

[13] See also the following claim by the primitivist Watkins: "If someone wishes to claim that, on my account, colours should be called 'physical properties', then so be it. Likewise, if the relevant physical properties are, as Byrne and Hilbert maintain, surface spectral reflectances, if colours are realized by and only by surface spectral reflectances, then it might be maintained that colours are types of reflectances. So long as we are careful, so long as we don't conclude from this way of talking that colours are not sui generis, so long as we remember that colours are not reducible to the surface spectral reflectances that realize them, then, at least for the purposes of this paper, I have no objection. We can all be friends" (2005: 50).

[14] Note that the formulation "intrinsic properties" is not employed by Allen. Instead, he speaks of "constant properties". The roles played by these two notions are the same. Given the above reasoning, I take the difference as a merely terminological one.

to derive the illumination-independence of colors from color constancy, as suggested by Byrne and Hilbert (2003).[15] The second way is to derive the mind-independence of colors from color constancy, as proposed by Allen. Although both rely on a similar formulation of the phenomenon, the first requires much stronger premises than the second. As discussed in Section 2.2, Byrne and Hilbert's route requires the truth of representationalism, a strong commitment. In comparison, as will become clear, Allen's route avoids any metaphysics of perception, which is a merit. Byrne and Hilbert's route was rejected in Chapter 5. But this rejection does not apply to Allen's route exactly because Allen does not appeal to any metaphysical view of perception.[16]

Hence, Allen's argument is a good representative for reflectance-grounded objectivism.

Though calling his argument "the argument from colour constancy", Allen does not make its form explicit. Roughly, he first characterizes color constancy in these words: "the colours of objects are perceived to remain constant throughout variations in the conditions under which they are perceived, and so throughout variations in the way that objects appear as the perceptual conditions vary" (2016: 16), then concludes that Mind-Independence "provides a straightforward explanation of the phenomenon of colour constancy" (2016: 18).

As pointed out by Gert, "the argument from constancy to realism is so straightforward and simple that it is typically not presented with a great deal of rigor" (2016: 127). Thus, in order to examine the argument, it is helpful to reformulate it with more rigor. Here it is:

Premise 1: Color constancy is perceptual constancy.

Premise 2: Color constancy is properly characterized by Allen's formulation.

Premise 3: Color constancy under Allen's formulation is the key explanandum of color phenomenon for any acceptable color theory.

Premise 4: Mind-Independence is the best explanans of color constancy under Allen's formulation.

Conclusion: Mind-Independence is a key thesis of any acceptable color theory.

Regarding Premise 1, Allen claims that "colour constancy is just one of a number of perceptual constancies. Other properties that exhibit perceptual constancy include paradigmatically mind-independent properties like shape and size" (2016: 17). Thus, color constancy is a perceptual phenomenon rather than a cognitive phenomenon or about a

[15] See Section 2.2 for the relevant discussion.

[16] As mentioned in footnote 11 of this chapter, a naïve realist theory of perception is a background commitment of Allen. Namely, even if a naïve realist theory of perception is false, it does not follow that primitivism is false.

property of objects themselves. This view is shared by many proponents of reflectance-grounded objectivism. For instance, compare Tye's formulation of color constancy: "I take color constancy … to be constancy in how things look color-wise through different lighting conditions. It is not constancy in color, period" (2012: 303).

Premise 2 affirms Allen's formulation of color constancy, which builds upon Premise 1. Similar formulation can be found among proponents of reflectance-grounded objectivism, for instance, Tye's formulation, cited above, and Byrne and Hilbert's formulation.[17]

Premise 3 builds upon Premise 2. Premise 3 is not made explicit by Allen, but it highlights a merit of the argument: it involves a general criterion useful for evaluating various competing color theories. Nevertheless, Premise 3 is implied by Premise 4. If Premise 4 is true, Premise 3 must be true as well.

Regarding Premise 4, Allen states that "[t]he claim that colours are mind-independent properties whose nature and existence is independent of the varying appearances presented across different perceptual conditions provides a straightforward explanation of the phenomenon of colour constancy" (2016: 18). At first sight, Mind-Independence does straightforwardly explain color constancy under Allen's formulation. If so, Premise 4 is true. From this follows the truth of Premise 3.

Accordingly, we can conclude that Mind-Independence is a key thesis of any acceptable color theory. However, can the argument establish Mind-Independence, as it claims? This we will discuss in the next section.

7.4 The Argument from Color Constancy Disproved

This section examines and ultimately disproves the argument from color constancy. More specifically, in Subsection 7.4.1, I identify each premise's problems; Subsection 7.4.2 examines Allen's response to one identified problem, resulting in a charitable modification of the argument; and in Subsection 7.4.3, the modified argument is ultimately disproved.

7.4.1 The Presented Argument Exposed

In this subsection, each premise of the argument from color constancy will be examined, and their problems will be exposed.

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[17] Recall Byrne and Hilbert's formulation of color constancy in Section 2.2: "[C]olor vision of human beings and many other organisms exhibits approximate color constancy, … for instance, tomatoes do not seem to change color when they are taken from a sunny vegetable patch into a kitchen illuminated with incandescent light" (2003: 9).

Premise 1 claims that color constancy is a perceptual constancy. It is *prima facie* plausible, but a closer second look reveals that it is somehow defective. First, there is an important reason to deny the existence of color constancy *as* a perceptual constancy. Careful observations suggest that color constancy is not perfect. If there is no perfect color constancy, there is a question of what it means for color constancy to be a perceptual constancy in the first place.

One such observation is metamerism. Metamerism strongly suggests that perfect color constancy doesn't exist. Metamerism was mentioned in Subsection 7.1.2 and means that two objects with different SSRs can have the same color appearance under one illumination condition to the same perceiver, and have different color appearances under a slightly different illumination condition to the same perceiver. It follows that it cannot be the case that both objects exhibit perfect color constancy. At least one of them fails to exhibit perfect color constancy. The most plausible explanation is that perfect color constancy does not exist: there is no perfect constancy in an object's color appearance under different illumination conditions.[18] This induces a question: what does color constancy mean?

Recall Allen's formulation that "the colors of objects are perceived to remain constant throughout variations in the conditions under which they are perceived" (2016: 16). If there is no perfect color constancy, then it is hard to make sense of what "remain constant" means in the formulation.

It might be responded that there is no perfect color constancy but an *imperfect* color constancy exists as a perceptual constancy. Some theorists might add expressions like "roughly", "more or less" or "approximate" in their formulation of color constancy.[19] They might argue as follows: For a thermometer measuring an object that has a constant temperature, there are inevitably slight oscillations in the results due to tiny measuring errors or environmental temperature fluctuations. But this does not mean that the temperature isn't constant. Analogously, *imperfect* color constancy is due to these inevitable slight oscillations arising from a visual system detecting colors in the environment. It does not follow that there is no color constancy.

However, this reasoning does not help. Metamerism shows that the notion of imperfect color constancy is conceptually incoherent. As discussed in Subsection 7.1.2, the general version of metamerism shows that metamerism involves an intrinsic ternary correlation

[18] As discussed, metamerism is due to the fact that there are three classes of cone cells in the human visual system, which are sensitive to three different but overlapping intervals of wavelengths in the visible spectrum. It follows that it is quite implausible to assume that, even if perfect color constancy exists, it is grounded in properties of objects.

[19] Byrne and Hilbert (2003), for instance, use "approximate".

between color appearances, SSRs and illumination conditions, while the notion of *imperfect* color constancy implies that illumination is extrinsic to SSRs by some verbal maneuvers like inserting “roughly” or “approximate”, which is conceptually incoherent.

Second, color constancy conflicts with color science. In contemporary color science, color appearance models are the most commonly used models.[20] These models are based on the non-existence of color constancy. “When colors are closely examined, the lack of color constancy becomes extremely clear. The study of color appearance and the derivation of color appearance models are, in fact, aiming to quantify and predict the failure of color constancy” (Fairchild 2013: 140). Furthermore, there are substantial reasons for treating the related phenomena as chromatic adaptation rather than color constancy. In color science, “chromatic adaptation” refers to “the human visual system’s capability to adjust to widely varying colors of illumination in order to approximately preserve the appearance of object colors” (Fairchild 2013: 156).

Third, it is reasonable to believe that color constancy under Allen’s formulation is not a perceptual but rather a cognitive phenomenon, like perception-based inferential or counterfactual reasoning.

In favor of an inferentialist reading, it might be claimed that experience has taught us to construct the “real” color from the apparent color: the “real” color is not what we see but something inferred from the presented color appearance.[21] Thus, one should not confuse perception-based inference with phenomenological characterization, which mistakenly conceives color constancy as a perceptual phenomenon.

Cohen’s (2009) formulation of color constancy is an example of a counterfactualist reading. Cohen writes about the case where a cup is partially in shadow and partially illuminated by daylight:

> … that we should understand the judgment that the adjacent regions share a color as answering this question: would region R_1 (presented under illumination I_1) share a color appearance with region R_2 (presented under illumination I_2) if, contrary to fact, both regions were presented under the same illumination—namely, both under I_1 or both under I_2? On this construal, the subject’s judgment is not a judgment to the effect that the

[20] The color appearance models are a group of different models. But no single one is considered the standard. Conventionally, CIECAM02 (CIE Color Appearance Model 2002) might be the most widely used color appearance model, see Fairchild 2013.

[21] For instance, Russell gives an inferentialist reading of shape: “All these things are not commonly noticed in looking at a table, because experience has taught us to construct the ‘real’ shape from the apparent shape, and the ‘real’ shape is what interests us as practical men. But the ‘real’ shape is not what we see; it is something inferred from what we see” (1912: 5). A similar reading can be applied to colors.

> regions are occurrently manifesting a common color, but rather to the effect that the regions share a color that one of them is not occurrently manifesting. That is, the subject judges that, although the sunlit region looks different (in respect of color) from the region in shadow, the two regions would look the same (in respect of color) were they both viewed under sunlight. (2009: 56)

Thus, one should not confuse counterfactual reasoning with phenomenological characterization, which mistakenly conceives color constancy as a perceptual phenomenon.

Based on the above three points, Premise 1 lacks credibility.

We now discuss Premise 2, which claims that color constancy is properly characterized by Allen's formulation. Premise 2 is based on the notion of color constancy suggested by Premise 1. Even if we set aside the lack of credibility of Premise 1, Premise 2 is still problematic because Allen's formulation doesn't characterize the phenomenon properly. Recall Allen's formulation: "[T]he colours of objects are perceived to remain constant throughout variations in the conditions under which they are perceived, and so throughout variations in the way that objects appear as the perceptual conditions vary" (2016: 16). Here, two important factors are missing.

The first missing factor is the synchronic sense of color constancy. More specifically, Allen's formulation addresses only the diachronic, not the synchronic, sense of the phenomenon: the locution "remain constant throughout variations" is based on a diachronic change of illumination conditions. Allen further explicates the point: "A nice way of illustrating colour constancy is to turn on a desk lamp in an already illuminated room" (2016: 16). The notion "turn on a desk lamp" suggests the diachronic change of illumination conditions. The synchronic sense, however, is completely missing in Allen's formulation. To contrast this, it may be helpful to consider Chalmers's formulation of color constancy, which highlights the synchronic sense of the phenomenon:

> Color constancy is the phenomenon wherein instances of the same color in the environment, when illuminated by quite different sorts of lighting so that they reflect different sorts of light, nevertheless seem to have the same color. A paradigmatic example is a shadow: when we see a surface that is partly in shadow, although there is something different about the appearance of the shadowed portion of the surface, it often does not seem to us as if the object has a different color in the shadowed portion. One might say: although *there is a sense* in which the shadowed and unshadowed portions look different, *there is also a sense* in which they look the same. (Chalmers 2006: 39; my italics)

In Chalmers's formulation, the synchronic sense of color constancy is that the differently illuminated parts of an object look the same, which is completely missing in Allen's formulation. Note that in Chalmers's formulation no diachronic change of illumination conditions is mentioned.

The second missing factor is the variance aspect in the diachronic sense of color constancy. Even if we focus only on the diachronic sense, Allen's formulation can address only its constancy aspect, not its variance aspect. The locution "remain constant throughout variations in the conditions" only emphasizes the constancy aspect of the diachronic phenomenon, while its variance aspect is missing. Allen is aware of this problem and explains: "it takes a special effort of the will to notice variations in appearance as conditions change" (2016: 29). However, the *epistemic* difficulty of noticing the variations is not an adequate reason to ignore the *ontological* fact of their existence. If there is no variance aspect of color constancy, how can there be a constancy aspect? As observed by Cohen:[22]

> On the one hand, normally sighted subjects find that the two (successively presented) regions of interest are, in some sense to be explained, alike in apparent colour. And on the other hand, normally sighted subjects find that the two (successively presented) regions of interest are, in some sense to be explained, easily, obviously, and quickly visually discriminable in apparent colour. (2008: 63)

In short, the variance aspect and the constancy aspect are interdependent in the diachronic sense of color constancy. A sufficient formulation mustn't emphasize one aspect without emphasizing the other. Allen's formulation doesn't meet this requirement.

Hence, even if we ignore the problem of Premise 1, Premise 2 is still highly problematic.

We now turn to Premise 3, which claims that color constancy as characterized by Allen's formulation is the key explanandum of color phenomenon for any acceptable color theory. It, too, faces serious challenges.

Note that Premise 3 builds upon Premise 2. The problems of Premise 2 also manifest in Premise 3. More specifically, given that the synchronic sense and the variance aspect of the diachronic sense of color constancy are overlooked, there arises a doubt: how can color constancy under Allen's formulation qualify as, let alone be the key, explanandum for a color theory? Call it *the insufficient explanandum problem*. In the literature, the problem is noticed by Cohen (2008), Gert (2017) and Vivian (forthcoming). For instance, Cohen writes,

[22] For a similar analysis, see Mizrahi forthcoming.

> In the face of these data, an invariantist could reasonably cling to her characterization of the phenomenon if she could provide some reason for taking the half of the data that accords with invariantism (viz., invariance reaction/surface match data) seriously while ignoring the half of the data that does not (viz.,variance reaction/appearance match data). But I don't see what that reason would be, and I certainly don't see that one has been given. (2008: 11)

Actually, Allen is aware of this problem too and has a response. Allen's response appeals to carefully defined "apparent properties". Yet, due to the significance and length of the discussion about apparent properties, Allen's response will be independently examined in Subsections 7.4.2 and 7.4.3.

Even if we ignore the insufficient explanandum problem, Premise 3 has another serious problem: there is no *a priori* reason to assume color constancy as the key explanandum of color phenomenon for a color theory. Color phenomena are diverse. Some philosophers, such as Cohen (2009), choose color variation as the key explanandum of color phenomenon for a color theory. Moreover, there are good reasons to treat certain color phenomena as more important than color constancy. For example, Section 4.3 established that simultaneous color contrast (SCC) is more basic than color constancy. It follows that if color constancy is an explanandum, then SCC is a more crucial one.[23] However, there is not much hope that reflectance-grounded objectivism can explain SCC.[24]

Let us proceed to Premise 4, which claims that Mind-Independence is the best explanans of color constancy. Premise 4 is controversial because it is unclear by what criteria to judge whether a color theory (or some thesis of a color theory) *best* explains the phenomenon.

On the face of it, Mind-Independence can well explain the phenomenon. However, to establish it as the *best* explanans, one must compare it with other theories (or theses) and make a reasoned choice. Another theory might explain the phenomenon equally well and explanatory power is only one criterion; if other theories also explain the phenomenon well, one must further consider criteria like ontological parsimony, predictive power and verifiability.[25] The best theory is chosen by evaluating these factors while appropriately

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[23] In color science, accounting for SCC plays a critical role in choosing among different models of color measurement. Specifically, the main reason to favor the color appearance models over the CIE system of colorimetry is that the former can provide a more fine-grained scale to account for phenomena like SCC, while the latter cannot, see Fairchild 2013: Ch. 6.

[24] For instance, Byrne and Hilbert's (2003) attitude to simultaneous color contrast is to set aside it as an exception rather than explaining it (see Section 4.4).

[25] For a discussion of theory choice, see Gauch 2003, Ch. 8.

weighting them. Thus, the controversy is: how can Mind-Independence be judged to be the best explanans?

Allen does not answer this question. He simply takes Premise 4 as given, stating: "The claim that colours are mind-independent properties … provides a straightforward explanation …" (2016: 18). This seems to imply that Allen agrees that a straightforward explanation is the best.[26] However, a straightforward explanation is not always best. For instance, the phlogiston theory posits phlogiston, which straightforwardly explains burning, but this does not make it correct, let alone the best explanation. Straightforwardness is only one theoretical virtue, not the sole determinant of the best theory. Assuming a straightforward explanation as the best one makes Premise 4 controversial.

Of course, the above analysis does not refute Premise 4. Mind-Independence might indeed prove to the best explanans. However, this requires careful consideration of factors like ontological parsimony, explanatory power, predictive power and verifiability. This is no simple task. For instance, the thesis that colors are illumination-independent properties can explain the phenomenon just as well as Mind-Independence, requiring meticulous comparisons between the two theses, which is not a simple task.

Hence, Premise 4 is controversial. It is unclear how Mind-Independence best explains the phenomenon.

In summary, given the identified problems of each premise, it is reasonable to doubt the argument' conclusion. However, one point remains untouched: the insufficient explanandum problem with respect to Premise 3. This will be discussed next.

7.4.2 The Exposed Argument Modified

How does Allen respond to the insufficient explanandum problem concerning Premise 3? In this subsection, I first present Allen's response and then argue that it strongly suggests a modification of the argument from color constancy. As a result, the modified argument will be able to solve some problems mentioned in the last subsection.

Recall the insufficient explanandum problem about Premise 3: Given that the synchronic sense, and the variance aspect in the diachronic sense, of color constancy are overlooked, there is a doubt: how can color constancy under Allen's formulation qualify as the key explanandum of color phenomenon for a color theory?

[26] This is clearly noticeable in his smooth transition from the use of "straightforward" to the use of "the best" in many places of the book, see Allen 2016: 14, 18, 21.

Allen is aware of the problem. He says there is "an important challenge for proponents of the Argument from Colour Constancy: to explain variations in experience due to changes in the perceptual conditions in a way that is consistent with the claim that we perceive colours to remain constant throughout these variations" (2016: 33). Allen has a response, which crucially relies on carefully defined "apparent properties". What is his account of apparent properties? Allen states:

> [A]pparent properties are mind-independent relational properties: they are relational properties in the sense that their identity is jointly determined by an object's constant properties and the perceptual conditions under which it is presented; and they are mind-independent in the sense that their nature and existence are independent of the psychological responses of perceiving subjects. Apparent colours are determined by the colour of the object and the nature of the illuminant and the colour of the background; apparent shapes are determined by an object's shape plus its spatial orientation; and apparent sizes are determined by an object's size plus its distance from the eye.
>
> Apparent properties play a … role in accounting for variations in perceptual experience across different perceptual conditions …. (2016: 36)

How can one notice apparent properties? Allen writes:

> When we attend to a shadowed region by screening off the surrounding context, we appear to be aware of a colour-related property that is neither the colour of the object in shadow nor a property of the illumination as such. … I will call the colour- … related properties that we attend to in these ways apparent properties. (2016: 35)

The crux of this account is that apparent properties are illumination-*dependent* but mind-*independent* properties. This account allegedly has many merits.[27] The primary one is that it can explain the synchronic sense of color constancy and the variance aspect in its diachronic sense. Take the synchronic sense of color constancy as an example: when a cup is partially shadowed and partially unshadowed at a given moment, the shadowed and the unshadowed regions appear different in one sense and the same in another sense. The difference can be explained by the contrast between two apparent color properties, while the sameness can be

[27] According to Allen, apparent properties can account not only for various aspects of perceptual constancy phenomena, but for occasions where perceptual constancy breaks down, as well as for perceptual errors, etc. (2016: 36–37).

explained by the actual constant color properties. Thus, the diachronic sense of color constancy is fully explained. A similar analysis applies to the variance aspect in the diachronic sense of color constancy.[28]

At first sight, it seems that the above account of apparent properties neatly solves the insufficient explanandum problem. However, is this really so?

There is a problem: Allen's response to the challenge is dialectically circular. It presupposes the conclusion of the argument from color constancy. However, the challenge questions one of the argument's premises, whose falsity might undermine the conclusion. Thus, using the potentially flawed conclusion as the basis for the response is inappropriate.

Here is a clearer look of how Allen responds to the insufficient explanandum problem. First, Allen establishes Mind-Independence as the conclusion of the argument from color constancy (2016: 17). Next, he notices the challenge and writes that it "poses an important challenge for proponents of the Argument from Colour Constancy: to explain variations in experience due to changes in the perceptual conditions in a way that is consistent with the claim that we perceive colours to remain constant throughout these variations" (2016: 35). Finally, he assumes Mind-Independence and use it to introduces the notion of apparent properties, which are supposed to solve the problem. He writes: "apparent properties are mind-independent relational properties: they are relational properties in the sense that their identity is jointly determined by an object's constant properties and the perceptual conditions…" (2016: 36), where the existence of "constant properties" is established exactly by Mind-Independence.

Obviously, this response is dialectically circular. In his response to the challenge, Allen presupposes the truth of the argument's conclusion, while the challenge questions a premise, which could undermine the argument. Thus, it is inappropriate to establish apparent properties on the basis of Mind-Independence.

This does not mean that Allen's response can be refuted. The circularity problem is actually solvable. A comprehensive understanding of Allen's thought allows for modifying his argument.

Provided that Allen's formulation of color constancy can be modified to include the synchronic sense and the variance aspect in the diachronic sense of color constancy, and that Mind-Independence can be modified to include apparent properties, it naturally follows that

[28] The variance aspect in the diachronic sense of color constancy can be explained by the contrast between *apparent* properties at different times, while the invariance aspect in the diachronic sense of color constancy can be explained by a *constant* color property.

the argument from color constancy can be modified to avoid many of the problems discussed in Subsection 7.4.1. Call the modified argument *the argument from color constancy**.

Premise 1: Color constancy is a perceptual constancy.
Premise 2: Color constancy is properly characterized by Allen's formulation*.
Premise 3: Color constancy under Allen's formulation* is the key explanandum of color phenomenon for any acceptable color theory.
Premise 4: Mind-Independence* best explains color constancy under Allen's formulation*.
Conclusion: Mind-Independence* is a key thesis of any acceptable color theory.

"Allen's formulation* of color constancy" means the phenomenon where there is a salient sense in which an object's color appearance remains *constant* under varying viewing conditions, but there is also a less salient yet still discernible sense in which an object's color appearance *varies* under varying viewing conditions, where "varying viewing conditions" can be cashed out either synchronically or diachronically. "Mind-Independence*" means the mind-independence of color properties (constant colors and apparent colors).

The modified argument satisfies the principle of charity in two ways: (1) it respects Allen's original concerns in each modified point, (2) it ensures that the essence of Mind-Independence is preserved. For (1), there are two modified points: Allen's formulation* (of color constancy) and Mind-Independence*. Allen's formulation* respects the original formulation by emphasizing that the constancy aspect is more salient than the variance aspect,[29] but still captures both the synchronic and the diachronic sense of color constancy, which is missing in the original formulation. Mind-Independence* respects Allen's original concern because it combines Mind-Independence with Allen's account of apparent properties. Regarding (2), the essence of Mind-Independence is the mind-independence of color properties. This is satisfied by Mind-Independence* because according to Allen the newly included apparent properties are mind-independent.

Moreover, the modified argument retains many of the original's merits. It still involves a general criterion for evaluating various color theories and is established independently of the metaphysics of perception. Above all, Mind-Independence* remains a thesis not just of primitivism but also of reflectance-grounded objectivism.

[29] By comparison, the two aspects are treated equally in Chalmers' formulation: "One might say: although there is a sense in which the shadowed and unshadowed portions look different, there is also a sense in which they look the same" (2006: 39).

Furthermore, the modified argument makes the conclusion more powerful: Mind-Independence* has more explanatory power than Mind-Independence. It can account not only for all facets of color constancy but also for other color phenomena where color constancy breaks down, such as the case where a white wall appears red under red light.

In sum, the argument from color constancy* is a charitable and powerful revision. It seems to completely solve the insufficient explanandum problem.

Note, however, that despite these merits some significant limitations remain: the modified argument lacks a response to the doubts about the reality of color constancy, it ignores the challenge that color constancy may not be the key explanandum for a priori reasons, and it provides no specific criteria for selecting the best color theory.

Most importantly, is the modified argument plausible in the first place? This we will examine in the next section.

7.4.3 The Modified Argument Disproved

One crucial premise of the argument from color constancy* is Premise 4, which claims that Mind-Independence* best explains color constancy under Allen's formulation*. Premise 4 is important because it relates to the plausibility of constant and apparent color properties. One might doubt whether they really exist. If they exist, can we accurately (or veridically) see them under any viewing conditions? Given these doubts, I will in this subsection present an argument rejecting Premise 4 (of the argument from color constancy*). Call it *the argument from accurate perception*. Here it is:

Premise 1: If Mind-Independence* best explains color constancy under Allen's formulation*, then Allen's method of accurately perceiving apparent properties and constant properties must be tenable.

Premise 2: Allen's method of accurately perceiving apparent and constant properties is tenable iff it applies to all ubiquitous color phenomena observed under the same ordinary viewing conditions as color constancy.

Premise 3: It is not the case that Allen's method of accurately perceiving apparent and constant properties applies to all ubiquitous color phenomena observed under the same ordinary viewing conditions as color constancy.

Conclusion: It is not the case that Mind-Independence* best explains color constancy under Allen's formulation*

The argument is valid. We examine its soundness. Premise 1 is presupposed by Allen. If Mind-Independence* best explains color constancy under Allen's formulation*, then the follow-up question is how to accurately perceive apparent and constant colors. By analogy, if a theory is supposed to be the best scientific theory of domain *X*, it must provide some *verifiable* predictions about *X*. Given that color objectivism always depends on a notion of veridical perception, it is natural to ask how we are to veridically perceive these mind-independent colors.[30] Here, what is needed is simpler than how to veridically perceive colors – all we need is a method for accurately attending to apparent and constant colors. According to Allen, the method is as follows:

> Accurately perceiving an object's apparent properties requires us to screen off as far as possible the perceptual context from conscious attention, whereas perceiving an object's constant properties requires us to be aware of the perceptual context: the object's spatial orientation, its distance from the eye, or the illumination. (2016: 39)

According to this method, to perceive *constant* colors, one needs to be fully aware of the global perceptual context. To better perceive *apparent* properties, one needs to put extra effort into ignoring the perceptual context as much as possible, for example by screening off the surrounding context from attention.

Premise 2 specifies a sufficient and necessary condition for the tenability of the method: it must be applicable to all ubiquitous color phenomena perceptible under the same ordinary viewing conditions as color constancy. "The same ordinary viewing conditions" means that the viewing conditions are the same as those required to observe color constancy, such as typical daylight conditions for an individual with a normal human visual system. Thus, many abnormal color phenomena, such as after-images, hallucinatory colors or phenomena engendered by abnormal illumination conditions, are excluded. Premise 2 is important because it provides a general criterion for evaluating the method.

Premise 3 is the crux of the argument. Given the general criterion established in Premise 2, all that is needed is a counter-example. Simultaneous color contrast (SCC) is just that: Allen's method does not apply to SCC. As discussed in Section 4.3, SCC is ubiquitous, predictable, intersubjectively accessible and coherent with other color phenomena. Importantly, SCC is observable under the same viewing conditions as color constancy, which satisfies the above

[30] If no notion of veridical color perception can be given, then one may well doubt the existence of mind-independent colors. If no method for perceiving the veridical mind-independent colors is given, it is natural to doubt both the existence of mind-independent colors and of veridical color perception.

criterion, because it is more basic than color constancy. Consider Figure 7.2, which is an example of SCC:

Figure 7.2: “Chess pieces”.

The upper “chess pieces” regions and the lower “chess pieces” regions are physically identical.[31] When one attends to Figure 7.2 globally, it is obvious at first glance that the upper “chess pieces” regions look brighter than the lower “chess pieces” regions. If the perceptual context surrounding the “chess pieces” regions is screened off, one will find that for each pair, the two pieces making it up look the same.[32]

Following Allen’s method, what are the constant and the apparent colors in this case? According to Allen’s method, to perceive the *constant* colors, one needs to take into account the perceptual context. The result is that the constant colors of the upper “chess pieces” regions are brighter than those of the corresponding lower regions. To perceive the *apparent* colors, one needs to ignore the perceptual context. The result is that the apparent colors of the upper “chess pieces” regions are the same as those of the corresponding lower regions.

However, Allen’s method is untenable for a decisive reason: it gives an incorrect verdict of the constant colors. On the one hand, given that the upper and the lower “chess pieces”

[31] This can be easily realized. For instance, these “chess pieces” regions can be produced by mixing the same ink in the same way, or by printing the same layout of same-colored dots.
[32] Apart from screening off the surroundings, there are other methods to notice that the two regions look to be colored the same, such as putting a strip with a certain shade of grayness on the picture to link two regions.

regions are physically identical, their constant colors must look the same under the same ordinary viewing conditions. As mentioned, the assumption of the supervenience of phenomenal colors on physical properties is widely accepted among color objectivists.[33] Given that constant colors supervene on the underlying physical properties, if the underlying physical properties are identical, there should be no difference in the constant colors when they are viewed under the same ordinary viewing conditions. On the other hand, following Allen's method, the constant colors look different. Hence, the method gives an incorrect verdict of the constant colors.

Premise 3 is validated. The conclusion follows that Mind-Independence* does not best explains color constancy under Allen's formulation*.

How could Allen respond to the argument from accurate perception? In the remainder, I discuss two possible responses.

The first response is to reject Premise 2 by claiming that the sufficient and necessary condition for the tenability of the method is too demanding, since the method is required to apply to *all* color phenomena that can occur under ordinary viewing conditions. Instead, one should replace "all color phenomena" with "most color phenomena", which somehow excludes SCC.

This response is not convincing. The ubiquity, predictability, intersubjective accessibility and coherence with other color phenomena of SCC makes the response unsatisfactory. Since Allen's method is supposed to apply to color constancy, it is unclear how SCC can be excluded, given that it is more basic than color constancy. Moreover, how could Mind-Independence* be provide the best explanation if its method of accurately perceiving the constant colors fails to account for SSC, which is ubiquitous and more basic than the color constancy phenomenon Mind-Independence* aims to explain?

The second response is to reject Premise 1, with the reasoning: Both "chess pieces" regions do indeed have the same constant colors, and the upper ones do look brighter than the lower ones. That is, Allen's method fails. However, the failure of Allen's method does not mean the failure of all methods. If some method *can* account for the "false" impression that the two regions *just* look to have different constant colors, then Premise 1 fails.

This response brings a very dim hope. It is very difficult to present/find such a method because, in principle, the "false" impression must be accommodated by the mind-independent factors that can be attended to when one follows the method. Specifically, the "false" apparent

[33] Recall Allen's claim that "it is commonly assumed that colours at least supervene on reflectances" (2016: 53). Here, "colours" means constant colors. See also Section 4.2.

differences in constant colors must be accommodated by some perceptible mind-independent differences in the context. However, it is unclear what these perceptible mind-independent differences could be. The spatial arrangement of Figure 7.2's physical surface? The background? The illumination? In Section 4.5, I give a tentative account of SCC based on the notion of the spatial arrangement of physical surfaces. As mentioned, the view is not mature yet. It is now up to the proponents of reflectance-grounded objectivism to evaluate and substantiate this line of thought.

Therefore, it should be clear now that no sufficient response can be given to the challenge raised by the argument from accurate perception. Accordingly, it is fair to conclude that the argument from color constancy* is still not sufficient to establish Mind-Independence*. The modified argument is disproved.

8

Color-disposition-grounded Objectivism

The previous chapters have examined reflectance-grounded objectivism. This chapter discusses another approach of color objectivism: color-disposition-grounded objectivism. It is organized as follows: Section 8.1 presents three main versions of this approach and details their features: color dispositionalism, realizer functionalism and role functionalism. Section 8.2 introduces the color-related sciences, showing how theorists of this approach might misunderstand science. Section 8.3 presents an argument showing the conceptual conflict between color-disposition-grounded objectivism and electrodynamics. In Section 8.4, I discuss color variation under this approach.

8.1 Dispositionalism, Realizer Functionalism and Role Functionalism

As mentioned in Section 1.2, there are three main versions of color-disposition-grounded objectivism:

Color dispositionalism: A color property *c* is a disposition to look *c*-colored to certain perceivers in the relevant viewing conditions, where the disposition is realized by the microstructural properties of the physical objects that have the property. This view is defended by Dummett (1979, 1993), McGinn (1983), Peacocke (1984), McDowell (1985), Johnston (1992), and Levin (2000).[1]

Realizer functionalism: Pending empirical findings in science, a color property *c* is whatever realizes the functional role of disposing the physical objects that have the property to look *c*-colored to certain perceivers in the relevant viewing conditions, and the color *c* must be had by everything so disposed. This view is defended by McLaughlin (2003).

Role functionalism: A color property *c* is the functional role of disposing the physical objects that have the property to look *c*-colored to certain perceivers in the relevant viewing

[1] In the color debate, some versions of color dispositionalism are developed in the framework of a relationalist account of dispositions. According to these views, colors are not intrinsic dispositions but relational properties between objects and subjects, see Cohen 2009. McGinn (1996) also gives a sketch of this version of color dispositionalism, according to which colors are higher-order psychophysical relations between objects and perceivers. These versions of color dispositionalism are classified as role functionalism in the current discussion.

conditions, and the color *c* is realized by microstructural properties of the objects (pending empirical evidence in science). This view is defended by Cohen (2009).

Recall the discussions in Section 1.2, the three theories have two theses in common:

(a1) Colors are properties of material objects.

(a3) Colors are essentially color-disposition-related properties such that the objects having those properties are disposed to look colored to certain perceivers in the relevant viewing conditions, where the color dispositions are realized by the underlying intrinsic properties of material objects, as science tells us, such as microstructural properties and light-disposition-related properties (including the properties of reflecting light and of emitting light).

As discussed in Section 1.3, (a3) presupposes the Intrinsic Light Reflection Property Thesis (ILRP Thesis), which claims that the physical properties responsible for light reflection are intrinsic to material objects.

A previously unaddressed point is that (a3) is an incomplete thesis, as identifying the realizers of the disposition to look colored to certain perceivers in the relevant viewing conditions is an empirical issue. Further investigation can complete (a3) by decisively identifying these realizers. To my knowledge, most proponents of color-disposition-grounded objectivism are silent about this empirical issue, because they assume that the conceptual framework of (a3) can well accommodate the as-yet-unspecified candidate. McLaughlin and Cohen are rare exceptions to have opinions on the most promising candidates for the realizers:

> Thus, vision scientists look to more abstract properties such as light-dispositions. … A disposition to reflect or emit light predominantly of a certain wavelength will be a basis for the disposition to look a certain colour to P. … As concerns any colour, C, look for a light disposition that, when activated, would affect the opponent processing system in a manner that will produce a visual experience of C. … Byrne and Hilbert (1997: 265) claim that in the case of surfaces, such dispositions will be types of spectral reflectances, and restrict the strategy to the colours of reflecting surfaces. … The point nevertheless remains that we can try to locate colours among light dispositions by appeal to results from opponent processing theory. (McLaughlin 2003: 127–131)

> I take it that, on the best current scientific evidence, the realizers of the roles in question are physical (on any of the usual understandings of that term) and disjunctive, hence (on role functionalism) that colors are realized physically and disjunctively in the actual world (see Nassau, 1980). (Cohen 2009: 180)

Two opinions suggest that the candidates for the realizers are McLaughlin's light-disposition-related properties and Cohen's physical and disjunctive microstructural properties.[2] These are all *intrinsic* properties of material objects, which are the "[bases] for the disposition to look a certain colour to P" (McLaughlin 2003: 127).

Color-disposition-grounded objectivism is alleged to have some salient features. First, it respects common sense. As Levin puts it, "[D]ispositionalism about color …, at least upon reflection, provides an intuitively satisfying account of what colors are and how they are perceived" (2000: 151). A similar point has been discussed in Section 1.2, where color-disposition-grounded objectivism was motivated by the simple view of color.

Second, color-disposition-grounded objectivism respects science. As Levin claims, color dispositionalism "is consistent with what science takes the causes of our perceptions to be" (2000: 152). More specifically, color-disposition-grounded objectivism respects science because it solves the problem of multiple realizers by allowing that a color disposition can be multiply realized by different materials, as suggested by empirical science.[3] Put another way, it respects science because (a3) can accommodate whatever is empirically suggested by science.

Third, it respects the role of perceivers and illumination conditions in color perception, while still allowing for objects to have color properties even when there is no perceiver or no illumination. For instance, an apple manifests its redness to perceivers in daylight. At night, when there is no illumination for it to manifest the redness, the apple still possesses the property of being red, implying that it would appear red again if daylight were to return.

Fourth, it can account for many salient color variation phenomena at the intrapersonal, interpersonal and inter-species level. For instance, when one observes an apple twice, once by daylight and once under green light, the apple appears red the first time and green the second time. According to color dispositionalism, the red appearance is the manifestation of

[2] Note that McDowell mentions the microscopic textural properties of the objects' surfaces, which I assume to be microstructural properties. "No doubt it is true that a given thing is red in virtue of some microscopic textural property of its surface; but a predication understood only in such terms … would not be an ascription of the secondary quality of redness" (McDowell 1985: 134).
[3] See Johnston 1992, McGinn 1996, Cohen 2009.

the apple's redness under the right conditions, while the green appearance occurs under the wrong conditions.

Fifth, it provides an answer to the Sellarsian question about the relation between the scientific image and the manifest image.[4] For instance, Cohen writes: "it will give us a way of answering Sellarsian questions … if we follow role functionalism in identifying the colors with certain functional roles, we can understand the scientific project of attempting to specify the nature of colors as the empirical project that attempts to determine the physical (or, if it should turn out that way, non-physical) structures that happen to fill those functional roles in the actual world" (2009: 181).

The second of these two features is crucial for the following discussion, as it claims that the view respects science. This directly responds to the challenge from science in Section 1.1, which claims that no color theory should contradict the color-related sciences. In the literature, with McLaughlin and Cohen as rare exceptions to discuss scientific details, most proponents of the view merely assert that it is consistent with science without demonstrating how. They simply assume that (a3) can accommodate whatever is empirically suggested by science. However, how can these theorists claim consistency without a substantial discussion of science? How can they assert that their view respects science when the general scientific outlook on color does not support color objectivism? How can they ignore scientists' reasons for renouncing color objectivism? The next section will introduce the color-related sciences, showing how these philosophical color theorists might misunderstand science.

8.2 Misunderstanding Science

As mentioned in Section 1.1, no color theory should contradict the color-related sciences. There are many scientific fields related to color. To my knowledge, there are four interrelated fields of science relevant to color-disposition-grounded objectivism.[5] These are:

- *Color science:* the study of how the human eye reacts to physical stimuli, which includes branches like psychophysics, colorimetry (including spectrophotometry), color appearance models and computational color constancy. Importantly, in colorimetry, the sub-field called "spectrophotometry" is about the measurement of light reflection.

[4] See Sellars 1963. Roughly, the Sellarsian question is how to make sense of the apparent conflict between the world as it appears to us and the world as described by science.

[5] These fields, especially color science and physics, are relevant to reflectance-grounded objectivism. Thus, these fields are also relevant to color objectivism in general.

- *Visual science:* the study of the entire visual system and how humans register and process visual information, involving psychology, neurophysiology and genetics.
- *Physical chemistry:* the study of how light is absorbed by matter, with a focus on the different chemical and physical structures of materials, including ligand field theory, molecular orbital theory and band theory.
- *Physics of light–matter interaction:* the study of how light interacts with matter, with a focus on the mechanism of light–matter interaction according to different understandings of the nature of light, including electrodynamics, quantum electrodynamics, atomic and sub-atomic physics. Importantly, in electrodynamics, a sub-field called the theory of electromagnetic radiation is specifically about the generation and propagation of electromagnetic waves.

To analyze whether color-disposition-grounded objectivism respects science, it is not necessary to examine all four fields. Instead, focusing on color science and physics suffices, because these fields overlap. Color science overlaps with visual science in the physiology of the visual system associated with color perception. Thus there is no need to consider visual science. Likewise, physics is the foundation of physical chemistry. In principle, the theoretical models of physical chemistry can be explained by those of physics, such as quantum mechanics, statistical mechanics and electromagnetism, among others. Thus there is no need to consider physical chemistry in particular.

Accordingly, to analyze whether color-disposition-grounded objectivism respects science, I will discuss how color scientists and physicists account for the nature of color, respectively.

What is the color scientists' view of colors? To have a glimpse of color scientists' view of colors, it is helpful to cite the definition of color employed by the International Commission on Illumination (CIE), which provides the international standards on many scientific issues related with light, color, vision, image technology, etc. In the international standard CIE S 017: 2020 ILV, (perceived) color is defined as the "characteristic of visual perception that can be described by attributes of hue, brightness (or lightness) and colourfulness (or saturation or chroma)". Note that this definition does not mention properties of objects, including color-disposition-related properties, at all.

Proponents of color-disposition-grounded objectivism may deny that this definition conflicts with their view. They may argue that, just like number theory in mathematics is about the properties of integers, which are independent of the metaphysical question "What are numbers?", color science is about the correspondence relation between the perceived color and the quantified hue, brightness and saturation, which is independent of the metaphysical question "What are colors?" However, this dispute can be set aside by considering color scientists' metaphysical view of color. For instance, Judd and Wyszecki, the leading color scientists in the 20^{th} century, state:

> … color, itself, is not purely physical or purely psychological. It is the evaluation of radiant energy (physics) in terms that correlate with visual perception (psychology). This evaluation rests squarely on the properties of the human eye. (1975: 5)

Judd and Wyszecki's view does not factor in the properties of objects, either. "Radiant energy" is physical, but it is categorically different from the color-disposition-related properties that color-disposition-grounded objectivism postulates. Put another way, rather than material objects it is radiant energy and psychological processes which are relevant for scientific color ontology. In short, color science conflicts with color-disposition-grounded objectivism. A brief recapitulation of the history of color science may help to explain the conflict.

Historically, color science belonged to physics. It was born from the works of physicists. Young's (1802) critical paper "On the Theory of Light and Colours", together with Helmholtz's (1856) additional empirical researches, which are together called the Young–Helmholtz theory, paradigmatically changed physicists' views on the nature of color. The paradigmatic shift was that physicists stopped endorsing the view that the nature of color resides in non-psychological factors. Instead, physicists began to believe that the nature of color lies on the subjective side. Young–Helmholtz theory quickly became common ground among physicists. As stated by Maxwell:

> It seems almost a truism to say that colour is a sensation; and yet Young, by honestly recognizing this elementary truth, established the first consistent theory of colour. So far as I know, Thomas Young was the first who, starting from the well-known fact that there are three primary colours, sought for the explanation of this fact, not in the nature of light, but in the constitution of man. (2010: Vol 2, 267)

Following this paradigmatic shift, with the further developments in the research on color vision, like Hering's (1878) opponent process theory of color vision, the spectrophotometer and colorimetry in the early 20^{th} century and the various color appearance models since the late 20^{th} century, color science has become a mature field. Color science has its roots in physics, but it establishes itself as a distinct field by incorporating both the physical theories of light and the psychology of color perception as its two cornerstones. Currently, color science has many branches, underpinned by psychophysics, the empirical study of the quantitative relation between physical stimuli (like daylight understood as radiant energy), as the independent-variable side, and the resulting perceptions (like perceived white under daylight conditions), as the dependent-variable side. Based on psychophysics, branches such as colorimetry, color appearance models and computational color constancy have emerged.

Describing the above empirical correlations requires no notions of object properties, let alone color-disposition-related properties. Color scientists seldom consider colors as properties of objects, for example, color-disposition-related properties,[6] simply because perceived, or psychophysical, colors cannot be captured by these categories. They need only radiant energy as suggested by physics as the objective side of the correlation, which is not a property of objects.

For color-disposition-grounded objectivism to respect color science, the theorists need to account for radiant energy in terms of the properties of objects in a proper way, such that the objective (or independent-variable) side of the correlation is accommodated by the properties of objects. Accordingly, the ILRP Thesis, which claims that the physical properties responsible for light reflection are intrinsic to objects, must be presupposed by (a3) as a response to this challenge.[7] However, can the ILRP Thesis account for radiant energy?

This redirects the discussion to the philosophy of physics, specifically the philosophy of physical theories of light reflection. Whether the ILRP Thesis respects the physical theories of light reflection is the topic of the next section. Now, we first need to show that theoretical physicists do not support color-disposition-grounded objectivism.

How do theoretical physicists view colors? As mentioned in Section 1.1, theoretical physicists are very likely to be color objectivists due to a grasp of the best physical theories both of matter and of light–matter interaction. However, they never endorse color objectivism, let alone color-disposition-grounded objectivism. Here are two representative claims made by the renowned theoretical physicists Feynman and Carlo Rovelli:

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[6] See the following classic textbooks in color science: Judd and Wyszecki 1975, Wyszecki and Stiles 1982 and Fairchild 2013, none of which discuss the notion of colors as properties of objects.

[7] Likewise, thesis (a2) of reflectance-grounded objectivism must presuppose the ILRP Thesis to account for radiant energy.

> Color is not a question of the physics of the light itself. Color is a sensation, and the sensation for different colors is different in different circumstances. (Feynman, 2013/1963: Vol. I, Ch. 35)[8]

> We see the world around us in colour. What is colour? Put simply, it is the frequency (the speed of oscillation) of the electromagnetic wave that light is. If the wave vibrates more rapidly, the light is bluer. If it vibrates a little more slowly, the light is redder. Colour, as we perceive it, is the psychophysical reaction of the nerve signal generated by the receptors of our eyes, which distinguish electromagnetic waves of different frequencies. (Rovelli, 2016: 45)

These two views are different. On Feynman's view, colors are contextual sensations. On Rovelli's view, (perceived) colors are psychophysical ways of distinguishing electromagnetic waves of different frequencies.

Despite the difference, these views have in common that colors are not conceived as properties of objects, including color-disposition-related properties. One may wonder whether this is due to physicists' unfamiliarity with color-disposition-grounded objectivism. If they were more philosophically driven, they would perhaps find that this view is compatible with physics. However, it does not seem so. Though rare, theoretical physicists sometimes comment on the metaphysics of color. For instance, Schrödinger claims that the traditional metaphysical distinction between primary and secondary qualities is a "prejudice" and even suggests that "one should not try to prove it false" (1964: V). He states:

> There is no reason why the perceptions of shape and movement which we form of our environment should be supposed to inhere any more strongly in a 'really existent' world of bodies than those of colour, sound, heat, etc. Both kinds are really there in our world of sensation. (1964: V)

[8] Feynman gives two chapters on color in *The Feynman Lectures on Physics*: "Chapter 35. Color Vision" and "Chapter 36. Mechanisms of Seeing".

Note that Schrödinger, an expert in color science, made important contributions to the field.[9] The cited text pertains to the distinction between primary and secondary qualities,[10] which also applies to color-disposition-grounded objectivism: according to Schrödinger, colors are sensations rather than color-disposition-related properties of material objects.[11]

It is reasonable to believe that these physicists' views on color are compatible with physics. Therefore, it is reasonable to conclude that color-disposition-grounded objectivism conflicts with, rather than respects, physics. The reason is that the physical theories of light reflection, like electrodynamics, tell us that light reflection cannot be accounted for by the intrinsic material properties of objects, as suggested by the ILRP Thesis. It follows that the physical stimuli which correlate with visual perception are more likely to be reflected light than material objects. A brief recapitulation of the history of the physical theories of light may help to explain the conflict.

Historically, since the late 17th century with Huygens' wave theory of light (1690) as a significant milestone, followed by Newton's *Opticks* (1704), Maxwell's theory of the electromagnetism of light (1860s), and quantum electrodynamics (1940s), the development of physical theories of light increasingly deepened our understanding of light and light reflection.[12] Roughly, there are three stages in the development: geometrical optics, electrodynamics and quantum electrodynamics.

In geometrical optics, light is understood as a collection of rays that can travel in space according to certain geometric rules. Most laws in geometrical optics only tell us how light behaves from a macroscopic viewpoint, which does not touch deeply on the nature of light. We study light reflection by focusing only on describing how light behaves when it encounters a material medium. For instance, the law of reflection ("The angle of incidence is equal to the angle of reflection") is a geometric rule of how light should behave when it encounters a material medium like a mirror.

In electrodynamics, light is understood as electromagnetic waves consisting of an electric and a magnetic field oscillating with certain frequencies. The transmission of light and the interaction of light with matter are described by the Maxwell equations. Light–matter

[9] See Schrödinger's papers "A Theory of Pigments of Maximum Luminous Efficiency" (1920), "On the Origin of the Eye's Sensitivity Curves" (1924) and "On the Relationship Between the Four-Color and Three-Color Theories" (1925).
[10] He disputes the traditional distinction between primary and secondary qualities primarily because there seems to be an insurmountable barrier in whether a question like "Is it really certain that you see the green of this lawn exactly as I see it?" can be answered or has any meaning (1964: V).
[11] It is clear that Schrödinger's comment applies to all main versions of color objectivism.
[12] These developments in physics ultimately led to the maturity of spectrophotometry in the early 20th century, which, by allowing physicists to measure the intensity of reflected light across different wavelengths, gave rise to color science.

interaction includes reflection, refraction and scattering, among other things. Specifically, light reflection is understood as the process in which incoming electromagnetic waves interact with the boundary area between two media, such as air and a mirror. This interaction results in changes to the characteristics of the electromagnetic waves, such as their direction, intensity and polarization, among others. Importantly, in this process, the outgoing electromagnetic waves can further be understood as the *re-radiated* electromagnetic energy that is radiated by temporarily induced radiators instantiated in the process.[13] Note that electrodynamics is widely employed in many other scientific fields, such as spectrophotometry, signal theory and materials science.

In quantum electrodynamics, light is understood as consisting of individual photons. The behavior of photons in photon–matter interaction, including photon reflection, is described statistically by quantum electrodynamics. Quantum electrodynamics provides the best understanding of light reflection so far. Importantly, experiments in quantum electrodynamics show that the reflection of many photons exhibits a stable statistical structure in an epistemic sense, but that the reflection of a *single* photon is completely unpredictable in a metaphysical sense.[14]

As a result, describing light reflection requires no notions of object properties, let alone color-disposition-related properties. The nature of light reflection cannot be captured by these categories. Moreover, it is quite implausible for a theoretical physicist to endorse the ILRP Thesis, which claims that the physical properties responsible for light reflection are intrinsic to material objects. For instance, in the *Feynman Lectures on Physics* about electrodynamics, Feynman makes it clear: "We want to emphasize that the amplitude of a surface reflection is not a property of the *material,* as is the index of refraction" (2013/1963: Vol. II, Ch. 33; italics in the original). My understanding of this is that material properties are responsible for light absorption or transmission in a material medium, while surface reflection is categorically different: it happens at the boundary between *two* media.[15]

[13] For a detailed discussion of temporarily induced radiators, see Section 3.5.

[14] See Section 3.6 for a detailed discussion. Note that "a stable statistical structure" is not a probability structure. The former is an epistemic notion, while the latter has a metaphysical connotation. Specifically, the notion of a probability distribution seems to presuppose a realist interpretation of quantum electrodynamics or quantum mechanics, which implies that the nature of a photon is probabilistic. This stance does not stand out among all metaphysical interpretations of quantum electrodynamics or quantum mechanics. Importantly, there is a sense that this interpretation is irrelevant to what the *experiment* of the partial reflection of light straightforwardly demonstrates: the complete unpredictability of the behavior of single photons.

[15] For instance, Feynman writes: "So there is a general rule that if any material gets to be a very good absorber at any frequency, the waves are strongly reflected at the surface and very little gets inside to be absorbed" (2013/1963: Vol. II, Ch. 33).

Given the above analysis, it is clear why color-disposition-grounded objectivism conflicts with, rather than respects, the color-related sciences.

One remaining issue. As discussed, unlike most other theorists, McLaughlin and Cohen are rare exceptions in that they engage in discussing scientific details. In the following, I will comment on McLaughlin's and Cohen's appeals to science.

As shown in Section 8.1, McLaughlin appeals to light dispositions in visual science and to Byrne and Hilbert's view of reflectance (the SSR Thesis), both of which rely heavily on spectrophotometry in color science, as it measures light reflection, providing the basis for their further theorizing. As demonstrated in Chapter 3, the SSR Thesis is false. It follows that McLaughlin's appeal to science cannot be successful. Moreover, even if we ignore the falsity of the SSR Thesis, appealing to spectrophotometry without including the rest of physics has limitations. Although spectrophotometry tells us a lot about matter–light interaction (see Section 3.4), many important questions remain untouched upon. One issue is the physical meaning of SSR. What does an SSR, being a unitless ratio, mean? What does an SSR really represent? Spectrophotometry provides a limited understanding (see Sections 3.3 and 3.7). Another, more important issue is that spectrophotometry ignores the micro-mechanism of light reflection, meaning that SSR can only be understood as an overall property, rather than a more specific property, of the underlying micro-mechanism. In physics, by comparison, there are already established theories that explain light–matter interaction. Electrodynamics is good enough to explain light–matter interaction, which suggests a metaphysical view of reflectance (see Sections 3.4 and 3.5). Nevertheless, quantum electrodynamics explains light reflection best (see Section 3.6). Without examining these physical theories and their metaphysical implications, how can McLaughlin's notion of light disposition be established?

I now turn to Cohen appeals to physical chemistry, as described in Section 8.1. He considers Nassau's (1980) work as providing the best evidence concerning what exactly realizes color-disposition-related properties.[16] The problem is that physical chemistry explains light absorption only in terms of the energy levels of atoms and the band structure of solids, based on their molecular and atomic structures,[17] which are completely irrelevant to how light is reflected. This is because physical chemistry alone cannot explain how colors are causally efficacious in whatever sense. Since all color objectivists, including Cohen,[18] presuppose the causal efficacy of colors, it follows that Cohen's appeal to physical chemistry

[16] On Cohen's view, a color-disposition-related property *c* is the functional role of disposing the physical objects that have the property to look *c*-colored to certain perceivers in the relevant viewing conditions.
[17] The band structure of solids is the hierarchy of energy levels that electrons in solids can occupy.
[18] Cohen claims that "role functionalists have a special reason to endorse it: their theory is one that takes colors to be constituted precisely by a role that is built from causal effects on subjects" (2009: 206).

cannot be successful. In physics, by contrast, there are established theories that provide a basis for the required account of causation, such as electrodynamics (see Section 3.5) and quantum electrodynamics (see Section 3.6). Without examining these physical theories and their implications, how can Cohen's appeal to physical chemistry be established?

In conclusion, color-disposition-grounded objectivism conflicts with, rather than respects, the color-related sciences.

How would proponents of color-disposition-grounded objectivism respond the above analysis? Just as some philosophers may initially assume that greater familiarity with philosophy would make physicists find their view compatible with physics, I hope that greater familiarity with physics will reveal the view's conflict with physics. However, some philosophers may try to avoid discussing any scientific details at all by insisting on a general statement: Given that (a3) is a conceptual claim, it can accommodate whatever is suggested on the empirical side by physics. Accordingly, physics, as an empirical science, cannot falsify (a3) due to the principled distinction between the conceptual and the empirical. I assume that many philosophers in the color debate firmly believe in this general claim. In the next section, I will show that this claim still conflicts with physics.

8.3 The Argument from A Priori Conflict with Electrodynamics

This section presents an argument that shows the conflict between the conceptual framework of (a3) and that of electrodynamics, which is called the *argument from the a priori conflict with electrodynamics*. Here it is:

Premise 1: Thesis (a3) implies that the primary physical properties responsible for light reflection are context-independent.

Premise 2: Electrodynamics implies that the primary physical factors responsible for light reflection are contextual.

Conclusion: If electrodynamics is true, then (a3) is false.

The argument is valid. We examine its soundness. Premise 1 is conceptually given by (a3). Thesis (a3) relies on the ILRP Thesis, the claim that the physical properties responsible for light reflection are intrinsic to material objects, which further implies that these physical properties are context-independent. A color property's being context-independent means that it remains the same regardless of circumstances. This entails that the primary physical properties responsible for light reflection, which underly the color properties of objects, must be context-independent. For instance, consider the redness of an apple in the dark, when there is no light to reflect: the apple's redness does not manifest, but the underlying physical properties responsible for its redness and light reflection remain unchanged. When exposed to sunlight, these properties are the same as they are in the dark, but they now manifest in the apple's reflecting light and appearing red to perceivers.

Note that, according to (a3), colors are essentially color-disposition-related properties, which can be relativized to the values of other parameters, for example, to certain perceivers and certain viewing conditions. This does not mean that colors depend on the occurrence of any specific contexts. For instance, the color dispositionalist McDowell writes, "No doubt it is true that a given thing is red in virtue of some microscopic textural property of its surface … an experience of something as red can count as a case of being presented with a property that is there anyway—there independently of the experience itself" (1985: 134). Thus, Premise 1 is validated.

Premise 2 is implied by electrodynamics. In electrodynamics, any light reflection must satisfy the boundary conditions conceptually derived from the Maxwell equations. For light reflection at the surface of a dielectric object, there are six boundary conditions, which are universal and do not depend on the specific context. As Feynman writes: "Our program has netted us the six relations between the fields in region 1 and those in region 2. … We want to emphasize, however, that the idea we have just used will work in *any* physical situation in which you have differential equations and you want a solution that crosses a sharp boundary between two regions where some property changes" (2013/1963: Vol. II, Ch. 33; italics in the original).

For a dielectric, non-magnetic object with medium 1 and medium 2 on two sides of its surface,[19] out of six boundary conditions, we only need to focus on the following one:

> $(\epsilon_0 E_1 + P_1)_x = (\epsilon_0 E_2 + P_2)_x$, where ϵ_0 is the permittivity of free space, E_1 and E_2 are the electric fields of light in medium 1 and medium 2, respectively, P_1 and P_2 are the polarization factors in medium 1 and medium 2, respectively, and x represents the direction orthogonal to the interface.[20]

[19] One medium is the material of the object itself and the other medium is what surrounds the object.
[20] Focusing on this condition is sufficient for most ordinary cases. The other five boundary conditions are $(E_1)_y = (E_2)_y$, $(E_1)_z = (E_2)_z$, $(B_1)_x = (B_2)_x$, $(B_1)_y = (B_2)_y$ and $(B_1)_z = (B_2)_z$. In light reflection by a dielectric, non-magnetic object, these conditions are trivially satisfied (see Feynman 2013/1963: Vol. II, Ch. 33).

This boundary condition applies both to how incident light penetrates into the object's surface and to how light radiates from the surface's underside as reflected light. The boundary condition holds universally for arbitrary contexts. But it clearly shows that E_1, E_2, P_1, P_2 and x are contextual.[21] E_1 and E_2 are given by the nature of the light in the given context. The *x*-direction is given by the direction of the light in the given context. What needs to be explained is the contextual nature of P_1 and P_2. The vector P_i (where i = 1, 2) represents the electric polarization of a material, which describes how the material's molecules interact with the electric field E of the incoming light. For dielectric objects, P is usually related to E by $P = \epsilon E$, where ϵ is the material's permittivity, which is relative to ϵ_0. Thus, P is also contextual, because both its direction and its value depend on those of E, given by the light in the relevant context. It follows that P_1 and P_2 are contextual.

What are the primary physical factors responsible for E_1, E_2, P_1, P_2 and x in a given context? The above analysis demonstrates that what is primarily responsible are the contextual factors of light. It follows that electrodynamics implies that the primary physical factors responsible for light reflection are contextual. For instance, consider how an apple reflects light in the dark: there are no contextual factors of light to satisfy $(\epsilon_0 E_1 + P_1)_x = (\epsilon_0 E_2 + P_2)_x$, and thus the apple *has no* color appearance. When there is sunlight, whose properties essentially constitute the context, the contextual factors in this situation are primarily responsible for light reflection by satisfying $(\epsilon_0 E_1 + P_1)_x = (\epsilon_0 E_2 + P_2)_x$, and thus the apple appears red due to the frequency E of the red light in the given context, ranging from about $4*10^{14}$ to $4.84*10^{14}$ Hz. Therefore, Premise 2 is validated as well.

We can conclude that if electrodynamics is true, then Thesis (a3) is false.

Now let us return to the general statement at the end of the last section: "Given that (a3) is a conceptual claim, it can accommodate whatever is empirically suggested by physics." What is the problem with it? The problem is the assumption that physics is no more than an empirical science, which misunderstands physics. A physical theory like electrodynamics is empirically verifiable, but it also has a conceptual framework in which to accommodate whatever is empirically observed. Importantly, the conceptual framework of a physical theory has metaphysical implications. When a color theorist designs a conceptual framework, it must (i) fit empirical findings, and (ii) be compatible with the conceptual framework of the related physical theories. Theorists of color-disposition-grounded objectivism only consider (i) while

[21] "Being contextual" means that these factors vary from context to context. This is different from a single property that manifests differently in different contexts (like a disposition intrinsic to an object), in which the property itself does not depend on context, only its manifestations do.

ignoring (ii). I will show the consequences of this neglect in a representative argument for color-disposition-grounded objectivism in the next section.

One remaining issue. One might wonder: What is the proper conceptual framework of a color theory that is compatible with electrodynamics? Moreover, can a version of color-disposition-grounded objectivism be developed that is compatible with electrodynamics?

For the first question, I assume that a version of color physicalism can be developed that is compatible with electrodynamics. Roughly, the idea is that, since the boundary conditions conceptually derived from the Maxwell equations can be perfectly understood as roles that any light–matter interaction must satisfy, a version of color physicalism based on an analysis of these roles can be developed as follows:

> *Realizer color physicalism:* A color *c* is whatever realizes/fulfills both the boundary conditions of light–matter interaction in electrodynamics and the role of disposing the matter in a light–matter interaction to look *c*-colored to certain perceivers in the relevant viewing conditions.

Note that "matter" means a physical material in one of several different possible states, including gas, liquid, solid and plasma. Thus, it applies not only to portions of matter that have a visible boundary, like ordinary material objects, but also to matter without any visible boundary, like air molecules in the atmosphere. As discussed in Section 3.6, oscillating dipoles are the causes of color experience. They are key properties of light–matter interactions, with the light playing a primary role in their excitation. In the current context, a visible region populated by oscillating dipoles is a promising candidate for the color-realizer in color physicalism. A great many color phenomena can be well explained by this view, such as material objects' stable color appearance under all kinds of illumination conditions, shadows, the blue of the sky, and the glow of the sunset, etc.[22]

Under the background assumption that color experiences are veridical and not considering quantum electrodynamics, the above realizer color physicalism may be the best theory a color physicalist can have.

For the second question, can color-disposition-grounded objectivism be somehow be compatible with electrodynamics? No, because this view relies on the ILRP Thesis, which conflicts with electrodynamics.

[22] This view cannot explain iridescence, as in the gradual change of colors on a soap bubble. To explain it, quantum electrodynamics is required. Besides, I also doubt whether this view can explain simultaneous color contrast.

8.4 The Argument from Color Variation Disproved

Section 1.1 mentions that one main challenge for a color theory is to accommodate the tension between two different kinds of color phenomena: color constancy and color variation. The former suggests that colors are perception-independent features of objects, while the latter means that colors are perception-dependent. Chapter 7 discussed how reflectance-grounded objectivism favors color constancy. In contrast, this section discusses how color variation seems to support color-disposition-grounded objectivism, and, most importantly, examines whether it actually does. I take Cohen's argument as representative, since it best illustrates the alleged support.

Cohen (2009: 24) writes the argument as follows:

(1) There are multiple, psychophysically distinguishable, perceptual effects (in respect of color) of a single color stimulus.
(2) There is no independent and well-motivated reason for thinking that just one of the variants catalogued at step 1 is veridical (at the expense of the others).
(3) Given that there is no well-motivated reason for singling out any single variant as veridical (at the expense of the others), an ecumenical reconciliation of the variants is preferable to an unmotivated stipulation in favor of just one of them.
(4) The best way to implement such an ecumenical reconciliation between apparently incompatible variants is to view them as the result of relativizing colors to different values of certain parameters, which is just to admit that colors are relations between objects and those parameters.

Thesis (1) is a brief description of color variation at intrapersonal level, which means that, under the same illumination, the same monochrome surface of an object exhibits different color appearances to the same perceiver.[23] Regarding (2), Cohen claims that "[t]he most important way of making this claim seem persuasive is to consider, in each instance, initially promising ways of settling on a single variant to the exclusion of others, and argue that these … are unsuccessful" (2009: 25). Thesis (2) is designed to reject an absolutist view of color. This view would assume that colors are non-relativistic, mind-independent properties of objects, which guarantees the existence of one preferred variant. Thesis (3) presupposes that color eliminativism is rejected (2009: 25). Color eliminativism is the view that objects do not possess color properties, suggesting that all color representations are non-veridical. Since

[23] See Figures 1.1, 1.2 and 1.3.

color eliminativism is rejected, (2) implies that "an ecumenical reconciliation of the variants is preferable to an unmotivated stipulation in favor of just one of them" (2009: 24). And (4) says that, to account for color variation, a relativist view of color is the best remaining theory, as a result of rejecting an absolutist view of color by (2) and color eliminativism by (3).[24]

In the literature, the debate surrounding this argument focuses primarily on (3). Some theorists think that (3) is false, because, properly understood, the nonexistence of a well-motivated reason for selecting any single variant as veridical does not entail that there is no veridical one.[25] In the scenario where a detective cannot identify the single murderer among many suspects, it would be false to conclude that due to this uncertainty the detective should accept that *all* of the suspects are murderers.[26] A similar analysis applies to (3). In response, Cohen argues that this case differs significantly from the color case. "As such, the mere existence of these classes of cases leaves unresolved the central question of how we should treat the disputed case of representational variation with respect to color" (2012: 2). Cohen seems to imply that the typical methodology of generalizing a notion from one case and applying it to a new one does not work for the color case. I agree completely. However, the problem is that this methodology is also employed by theorists of color-disposition-grounded objectivism. For instance, a color dispositionalist might generalize the notion of dispositional properties from cases like nausea or pain and apply it to color.[27] Similarly, a (realizer or role) functionalist might generalize a functionalist notion of a sensory quality to all kinds of sensory qualities.[28] It is unclear in which direction generalization should proceed and where to stop it. Given that this is a debate between color objectivists, I will not discuss it further.

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[24] For Cohen, a relativist view of color is color relationalism; for McLaughlin (2021), it is not.

[25] See Pautz 2010, Tye 2012.

[26] This case is a simplified version of Tye's example (2012). According to Tye, the reflection that, a priori, nothing can be both square and round at the same time suggests that it is false to conclude that an object is simultaneously square to one person and round to another. A similar analysis can be applied to the color case.

[27] Johnston uses this methodology in his formulation of color dispositionalism: "The remaining surface property which is a standard explanatory cause of visual experience as of canary yellow things, and hence the remaining candidate to be canary yellow, is the disposition to look canary yellow. Now the nature of a disposition to look a certain way may be revealed by a visual experience if that experience is appropriately construed. … Consider this example: twenty five years ago I felt nausea when I tasted a juicy apricot during a rough sea-crossing. I had the experience of nausea and I took it to be a manifestation of the power or disposition of juicy apricots to produce nausea in me during rough sea-crossings" (1992: 225).

[28] McLauglin uses this methodology to generalize his functionalist analysis of color to all sensory qualities: a functionalist analysis of color "is also intended to hold for visual properties such as highlighting, glaring, glowing, gleaming, glinting, glistening, glittering, and the like. Moreover, it can be extended to sensory qualities in the aural, gustatory, olfactory, and tactual modalities—to qualities such as the loudness, pitch, and timbre of sounds, the sweetness, saltiness, sourness, and bitterness of tastes, the putridness of odours, the roughness of tangible surfaces, etc. The account can thus be generalized as an account of sensory qualities" (2003: 100).

In the remainder, I will address what I take to be the most serious problem of the argument: even if we accept (1), (2) and (3), the conclusion, (4), does not follow. More specifically, (4) suggests that "colors are relations between objects and those parameters" (2009: 24), while the term "object" used therein never appears in (1), (2) or (3). Thus, the argument is neither valid nor sound.

The charitable reading is that Cohen presupposes that the "color stimulus" in (1) is the same as the "object" in (4). However, is a (material) object really a color stimulus?

The color-related sciences do not suggest so. As discussed in Section 8.2, psychophysics, which underpins color science, suggests that a color stimulus is radiant energy. Recall that psychophysics is the empirical study of the quantitative relation between physical stimuli (like daylight understood as radiant energy), as the independent-variable side, and the resulting perceptions (like perceived white under daylight conditions), as the dependent-variable side. What is radiant energy? According to electrodynamics, in the case of light reflection by dielectric materials, which includes most ordinary objects, radiant energy is the energy radiated by temporarily induced oscillating dipoles instantiated in the process of light reflection.[29] Oscillating dipoles are properties of light–matter interaction, with light playing the primary causal role in their instantiation. They are *not* properties of material objects. Hence, according to the color-related sciences, material objects cannot be color stimuli.

For color-disposition-grounded objectivism to respect science, it needs to account for radiant energy in terms of properties of objects. Accordingly, it must be conceptually compatible with electrodynamics, which compatibility, however, has been disproved in the last section. It follows that if electrodynamics is true, the presupposition that the "color stimulus" in (1) is the "object" in (4) is false. The argument cannot be sound.

As mentioned in the last section, the conceptual framework of a color theory must (i) fit with empirical findings and (ii) be compatible with the conceptual framework of the related physical theories. Given that color-disposition-grounded objectivism only considers (i) but ignores (ii), the manifestation of this neglect in the above argument is that it mistakenly presupposes the identity of "color stimulus" and "object", which inevitably conflicts with science.

[29] For a detailed discussion of temporarily induced oscillating dipoles, see Section 3.5.

PART III

THE ANTI-OBJECTIVSIT VIEW CONCLUDED

9

Conclusion: Color Objectivism Debunked

Part I and Part II thoroughly examined and rejected all main version of color objectivism. This concluding chapter (Part III) establishes the main thesis of the dissertation: anti-objectivist view of colors. It is a general rejection of color objectivism. The chapter unfolds as follows. Section 9.1 discusses the argument for the anti-objectivist view of colors, along with a summary of the findings of the dissertation. Section 9.2 outlines four applications of this argument. Section 9.3 presents eight anti-objectivist color theories that spell out the anti-objectivist view of colors in different ways.

9.1 The Argument for the Anti-objectivist View of Colors

The anti-objectivist view of colors is that it is not the case that colors are properties of material objects. As presented in Section 1.4, the argument for the view is as follows:

Premise 1: Color objectivism is true if and only if (a1) is true.
Premise 2: The truth of (a1) is equivalent with the truth of the disjunction of (a2) and (a3).
Premise 3: (a2) is false.
Premise 4: (a3) is false.
Conclusion: Color objectivism is false (the anti-objectivist view of colors is true).

The argument is valid. We examine its soundness. The first two premises are conceptually true. For Premise 3, (a2) presupposes the SSR Thesis,[30] which is rejected in Sections 3.2–3.5 via four arguments (from the perfect reflecting diffuser, reflectance in spectrophotometry, reflectance in electrodynamics, and oscillating dipoles in electrodynamics). Thus, (a2) is false and Premise 3 is validated. For Premise 4, Section 8.3 shows that if electrodynamics is true, then (a3) is false.[31] Since electrodynamics holds when quantum phenomena are not

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[30] Recall that (a2) is that colors are essentially SSR-related properties which are intrinsic properties of physical objects, where SSRs are posited by science. The SSR Thesis is that SSRs are illumination-independent intrinsic dispositional properties of physical objects, posited by science. Thesis (a2) presupposes the SSR Thesis because all three main versions of reflectance-grounded objectivism presuppose the SSR Thesis (see Section 2.2, Section 3.1, Subsections 7.1.1 and 7.2.2).

[31] Recall that (a3) is that colors are essentially color-disposition-related properties such that the objects having those properties are disposed to look colored to certain perceivers in the relevant viewing conditions, where these color dispositions are realized by the underlying intrinsic properties of material objects, as science tells us, such as microstructural properties and light-disposition-related properties (including the properties to reflect light and the properties to emit light).

considered, (a3) is false and so Premise 4 is validated too. Therefore, the anti-objectivist view of colors is true.

Now we can summarize the dissertation's findings by evaluating whether color objectivism can meet the two challenges posed by color phenomenology and science, as outlined at the beginning of the dissertation.

Does color objectivism meet the challenge from science that it must accommodate the tension between the alleged objectivity of color and the metaphysical view of color implied by science (see Section 1.1)? No, it fails. Delving into the color-related sciences (see Section 8.2), the challenge means that color objectivism must account for radiant energy in terms of the properties of objects in a *proper* way, where radiant energy is the objective side of the correlation (established by color science) between physical stimuli, as the objective side, and the resulting perceptions, as the subjective side. Accordingly, the ILRP Thesis must be assumed by color objectivism.[32] However, the ILRP Thesis conflicts with science, especially with electrodynamics in physics. More specifically, in reflectance-grounded objectivism, the ILRP Thesis is specified as the SSR Thesis, which conflicts with both spectrophotometry (see Sections 3.3 and 3.7) and electrodynamics (see Sections 3.4–3.5). In color-disposition-grounded objectivism, the ILRP Thesis conflicts with electrodynamics (see Section 8.3). Hence, color objectivism conflicts with the color-related sciences.[33]

Does color objectivism meet the challenge from color phenomenology that it must accommodate the tension between color constancy and color variation (see Section 1.1)?[34] No, it fails. Above all, color objectivism is false due to the challenge from science, which strongly suggests that its responses to the challenge from color phenomenology cannot be adequate. For instance, in reflectance physicalism, the SSR Thesis is equivalent to the Color Thesis (see Chapter 2). The SSR Thesis is false due to its conflict with science, and that entails the falsity of the Color Thesis. This suggests that reflectance physicalism cannot adequately respond to the challenge from color phenomenology.

Moreover, even without considering science, color objectivism still struggles with the challenge from color phenomenology. Specifically, reflectance-grounded objectivism is claimed to be supported by color constancy, but Section 7.4 outlines the problems with this

[32] The ILRP Thesis is that the physical properties responsible for light reflection are intrinsic to objects. Note that Section 1.3 mentions that the ILRP Thesis is the common ground for evaluating color objectivism.

[33] Section 8.2 shows that it is not necessary to examine all the color-related sciences. Instead, focusing on color science and physics suffices, because these sciences overlap.

[34] Recall that color constancy means that the colors of objects appear to be roughly the same under various illumination conditions when viewed. Color variation means that, under the same illumination, the same surface of an object exhibits different color appearances to the same perceiver, or to different perceivers, or to perceivers from different species.

support. Similarly, color-disposition-grounded objectivism is alleged to be backed by color variation, which Section 8.4 shows to be problematic.

Furthermore, the color objectivists' phenomenology has its own issues. First, there is no a priori reason to favor it, as a color phenomenon can, in principle, be characterized differently (see Section 5.1). Second, it involves objects in its characterization, but this is not superior to the basic color phenomenology (see Section 5.1), which does not. Third, it presupposes that visual experiences carry information about both color and illumination conditions, which is arguably problematic (see Sections 5.4–5.5).[35] Fourth, it cannot adequately accommodate simultaneous color contrast, a ubiquitous color phenomenon (see Chapter 4 and Subsections 7.4.1 and 7.4.3). All these points suggest that the objectivists' phenomenology cannot adequately characterize color phenomena, let alone respond to the challenge from color phenomenology.

In addition, even without considering the challenges from both science and color phenomenology, color objectivism has difficulties with its metaphysics of dispositions and causation. One debate within color objectivism concerns the physical side of the causal process underlying a color experience. According to microstructural physicalism, the physical side must be the categorical bases of SSRs, rather than the SSRs themselves, because SSRs, as dispositional properties, are causally inefficacious. However, this approach faces the metamerism problem (see Subsection 7.1.2). According to other versions of color objectivism, the physical side can consist in SSRs (reflectance physicalism and color primitivism) or in whatever realizes (the dispositional properties responsible for) the dispositions to look colored to certain perceivers in the relevant viewing conditions (color-disposition-grounded objectivism) such that the related dispositional properties are causally efficacious. However, this approach faces the problem of causal overdetermination and, potentially, the problem of individuation (see Section 6.5).

9.2 Applications

The argument for the anti-objectivist view of colors has many applications. This section outlines four of them.

First, many distinctions in color objectivism can be rejected, including but not limited to:

[35] For one problem, the color appearance of an object can be characterized differently depending on how the relationship between color and illumination is interpreted. For instance, the same color appearance can be interpreted as shadowed, standard-illuminated, non-standard-illuminated or projected. There is no a priori reason to favor one of these interpretations, which leads to the indeterminacy of color phenomenology. Moreover, such interpretations are not even necessary, because one can simply characterize the scene as "the object appears to be c-colored".

- the distinction between the primary- and secondary-quality view of colors,[36]
- the distinction between strong and weak color physicalism,[37]
- the distinction between color relationalism and color non-relationalism,[38]
- the distinction between an absolutist and a relativist view of colors,[39]
- the distinction between realizer and role functionalism about colors.[40]

Second, many conceptual frameworks in color objectivism can be rejected, including but not limited to:

- the frameworks of color dispositions and their material bearers, [41] their categorical/causal bases,[42] or their (multiple) material realizers,[43]
- the framework of dispositions to reflect light and their categorical/causal bases.[44]

Third, the materialist notion of color properties can be rejected:[45]

- A color property is material only if it is identical to, or supervenes on, or is realized by the property posited by an account of the intrinsic natures of material objects and their constituents.[46]

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[36] In the color debate, this distinction is widely used to classify different versions of color objectivism. This is even reflected in the titles of many influential papers in the color debate, such as Boghossian and Velleman's "Color as a Secondary Quality" (1989), Jackson's "The Primary Quality View of Color" (1996), and Byrne and Hilbert's "Are Colors Secondary Qualities?" (2011).
[37] Dorsch (2009) uses it as the primary distinction to classify color objectivism.
[38] Cohen (2009) employs it to first argue against what he takes to be the standard taxonomy (with the primary distinction between color realism and color eliminativism) in the color debate, and then to set the stage for color relationalism.
[39] McLaughlin (2021) uses it to classify color objectivism. Note that he also emphasizes the difference between color relativism and color relationalism.
[40] See McLaughlin 2003 for a defense of realizer functionalism. See Cohen 2009 for a defense of role functionalism.
[41] See McLaughlin 2021.
[42] See Jackson 1996, McGinn 1996.
[43] See Johnston 1992, McLaughlin 2003, Cohen 2009.
[44] See Jackson 1996, Lewis 1997, Byrne and Hilbert 2003.
[45] At the end of Section 1.3, it is noted that for color objectivism, colors are material-related properties, regardless of their nature.
[46] Stoljar (2001) introduces this notion of physical properties: A property is physical only if it is identical to, or supervenes on, or is realized by the property posited by an account of the intrinsic natures of physical objects and their constituents. It applies to all main versions of color objectivism. For instance, for microstructure physicalism, colors are material in the sense that colors are identical with the constitutive microstructural properties of physical objects (posited by an account of the intrinsic natures of physical objects and their constituents).

Fourth, the metaphysical view of light reflection in color objectivism (the ILRP Thesis, which claims that the physical properties responsible for light reflection are intrinsic to objects) can be rejected. Actually, the ILRP Thesis represents the mainstream view among contemporary philosophers regarding the scientific outlook on light reflection. Recall Chalmers' summary:

> Science suggests that … [t]he properties of the object that are responsible for the reflection or radiation of the light appear to be complex physical properties, such as surface spectral reflectances, *ultimately grounded* in microphysical configurations. (2006: 20; my italics)

Note that the above distinctions, conceptual frameworks, the materialist notion of color properties, and the ILRP Thesis provide the basic supports for color objectivism. These could be very useful only if color objectivism is correct.[47] Since color objectivism is false, there is no need to preserve them.

9.3 Some Promising Approaches

As mentioned in Section 1.4, the anti-objectivist view of colors, as a negative thesis, is typically understood as following from certain positive theses in anti-objectivist color theories. However, in the dissertation, the anti-objectivist view of colors is established independently of any metaphysical assumptions about colors. Consequently, even if these positive theses fail, the anti-objectivist view of colors remains intact. Therefore, the proper understanding is that the former are different ways of spelling out the latter, while the latter is independent of the former. This section presents eight color theories as such concretizations.

First, the anti-objectivist view can be spelled out as realizer color physicalism (developed in Section 8.3), which claims that a color *c* is whatever realizes/fulfills both the boundary conditions of light–matter interaction in electrodynamics and the role of disposing the matter in a light–matter interaction to look *c*-colored to certain perceivers in the right viewing conditions. As mentioned, under a veridical notion of color experience and not considering quantum electrodynamics, this may be the best proposal a color physicalist can have.

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[47] For instance, some distinctions help contrasting reflectance physicalism and color primitivism. Both are absolutist views of color. Reflectance physicalism is a type of strong physicalism, identifying colors with properties posited by physics, while primitivism is a type of weak physicalism since it does not. This puts primitivists in a defensive stance, as the properties posited by physics are prima facie good candidates for colors. As put by Byrne and Hilbert, "[t]he basic argument for primitivism, then, is …: the alternatives must be dispatched" (2003: 7).

Second, the anti-objectivist view can be spelled out as visual-system-grounded interactionalism about colors, which claims that colors are properties of interactions between visual systems and physical stimuli. This notion of color is commonly called "psychophysical color" in science. This view is held by many color scientists, visual scientists, theoretical physicists and philosophers of color science/visual science.[48] Its formulation varies from author to author. For instance, Chirimuuta's (2015) version is as follows:

> On the current analysis, colors are not properties of things (minds or extra-dermal objects) but of specific kinds of events, namely perceptual interactions: Colors are properties of perceptual interactions involving a perceiver (P) endowed with a spectrally discriminating visual system (V) and a stimulus (S) with spectral contrast of the sort that can be exploited by V. (2015: 140).

This view presupposes that the proper ontological category to locate colors in is an interactionalist notion of event, rather than the traditional substance–property distinction or the notion of event suggested by this distinction. This implies that interaction is more fundamental than the interacting items. In sum, this view is a type of (non-materialist) color physicalism that does not presuppose a veridical notion of color experience.

Third, the anti-objectivist view can be spelled out as sensationalist contextualism about colors, which claims that colors are sensations or aspects of visual experience. This notion of color is called "perceived colors" in science and "qualia" or "phenomenal qualities" in philosophy. This view is held by many theoretical physicists and color scientists. Feynman's version is as follows:

> Color is not a question of the physics of the light itself. Color is a sensation, and the sensation for different colors is different in different circumstances. (2013/1963: Vol. I, Ch. 35)

[48] For a defense from color scientists, see Judd and Wyszecki 1975. For a defense from visual scientists, see Parmer 1999. For a statement from theoretical physicists, see Rovelli 2016. For defenses from philosophers of color (or visual) science, see Giere 2006 and Chirimuuta 2015, among others.

Note that Feynman further emphasizes that one should not type color sensations at the interpersonal level in terms of the features of sensations of different perceivers.[49, 50] Instead, it is enough to study the conditions under which two stimuli are indistinguishable to the same perceiver.

A more refined version of this view is perhaps given by Wyszecki and Stiles:

> Color is that aspect of visual perception by which an observer may distinguish differences between two structure-free fields of view of the same size and shape, such as may be caused by differences in the spectral composition of the radiant energy concerned in the observation. In this sense, the term color is sometimes referred to as perceived color to distinguish it from color used in the sense of psychophysical color. (1982: 487)

"Structure-free fields of view" means that there are no patterns or variations in brightness within the observed area. "Caused" implies a regularity notion of causation rather than a realist notion of causal determination. The crux of this definition is that colors are the aspects of visual experience that enable the observer to phenomenally differentiate between two patches of the visual field.

These two views presuppose only color sensations or color aspects of visual experience. Namely, they presuppose neither a veridical notion of color experience nor commonly known frameworks in metaphysical realism. At the very least, this implies that sensations or aspects of visual experience are ontologically more fundamental than the properties of material objects.

Fourth, the anti-objectivist view *can be* spelled out as color eliminativism, which claims that material objects are not colored.[51] Color eliminativism is a minority position in contemporary philosophy.[52] However, it was a prevalent view among scientists and philosophers in the era of the Scientific Revolution, held by Galileo, Descartes and Locke,

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[49] "We do not have to decide whether, when one sees something green, what it feels like inside is the same as what it feels like inside someone else when he sees something green; we do not know anything about that" (Feynman, 2013/1963: Vol. I, Ch. 35).

[50] In comparison, color objectivists hold that it is epistemically safe to type color experience in terms of the features of the experience. Most color objectivists theoretically categorize color experiences without even explicitly mentioning what they are doing. McLaughlin (2021) is the rare exception that I know who makes the point explicit: "Hereafter, by 'the experience of red', I'll mean the experience with a certain distinctive (yet highly determinable) phenomenal character, one we are familiar with from our own case, given that we've had the experience. More generally, I'll hereafter type colour experiences just by their phenomenal characters" (2021: 33). Pay attention to the use of "we" in the sentence.

[51] Or, material objects do not have the colors that they ordinarily appear to have under normal illumination conditions.

[52] For defenses of color eliminativism, see Hardin 1988, Boghossian and Velleman 1989, Chalmers 2006, Maund 1995, 2006, Pautz 2006, Wright 2021 and Brown 2022.

among others. For instance, according to Locke, colors are secondary qualities, which are "nothing in the Objects themselves, but Powers to produce various Sensations in us by their primary Qualities, i.e., by the Bulk, Figure, Texture and Motion of their insensible parts" (1689[1975]: 2.8.10).[53]

What is the difference between the anti-objectivist view of colors and color eliminativism? The former says: "It is not the case that colors are properties of material objects." The latter says: "Material (or physical) objects are not colored." The latter entails the former, but not vice versa. For one thing, the former focuses solely on material objects, while the latter equates material objects with physical objects. The former implies a non-materialist physicalist notion of object that might be different from a materialist notion of object. For instance, it is quite plausible that light, constituted by photons, consists of non-material physical objects, since photons lack mass and don't occupy space, unlike ordinary material objects, such as the molecules of an apple. It follows that the anti-objectivist view can be spelled out as a light theory of color, where the claim "colors are properties of physical objects" still holds, while color eliminativism cannot.

For another thing, the former contains a form of negation-raising, while the latter has a form of local-scope negation. The use of "it is not the case that" indicates that the anti-objectivist view does not quantify over material objects. Thus, the anti-objectivist view can be developed not only within frameworks that assume material objects as fundamentally real, such as materialist, property dualist, substance dualist, and triple-realm metaphysics, among others,[54] but also within mentalist metaphysics, where objects are conceived as mental, such as in idealism and phenomenalism.[55] In comparison, color eliminativism is not compatible with a mentalist metaphysics.

Fifth, the anti-objectivist view can be spelled out as color mentalism, which claims that colors are mental properties. Color mentalism is a rather marginal position in contemporary philosophy. For instance, Boghossian and Velleman's (1989) color projectivism is that colors are projective properties of the mind:

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[53] Note that in the contemporary color debate, the *traditional* secondary-quality view of color is labeled as "color eliminativism" or "color irrealism". This is quite different from the *contemporary* secondary-quality view of color, which is a realist account of colors that is based on realism about color dispositions.

[54] For an introduction to physicalism, see Papineau 2001. For a defense of property dualism, see Chalmers 2006. For defenses of substance dualism, see Swinburne 2013 and Rickabaugh and Moreland 2023. For a defense of triple-realm metaphysics, see Russell 1912, where we assume that Russell's sense data constitute a non-mental, non-physical third realm.

[55] For defenses of idealism, see Foster 2008, Kastrup 2018, Chalmers 2019, Robinson 2022 and Builes 2023. For a defense of phenomenalism, see Pelczar 2019.

> We have argued, first, that visual experience cannot be adequately described without reference to intrinsic sensational qualities of a visual field; and second, that intrinsic colour properties of the visual field are the properties that objects are seen as having when they look coloured. … The projection posited by this account has the result that the intentional content of visual experience represents external objects as possessing qualities that belong, in fact, only to regions of the visual field. By "gilding or staining all natural objects with the colours borrowed from internal sentiments", as Hume puts it, the mind "raises in a manner a new creation". (1989: 96)

The anti-objectivist view can be spelled out as color projectivism in a property dualist metaphysics.

Sixth, the anti-objectivist view can be spelled out as a third-realm view of colors, which claims that colors are neither physical nor mental, but exist in a distinct third realm. There are two versions of this view. Pautz's (2006) version is that colors are primitive, non-instantiated existents:

> On the version I defend, there are primitive colour properties, and we are related to them in colour experience. We experience these properties as instantiated in physical space. But they are not instantiated by anything, including our own experiences. Therefore, there are no coloured *things*. On another, more radical version of Eliminativism, not only are there no coloured things, there are no colour properties, not even uninstantiated colour properties. I reject this more extreme version. (2006: 562–563; italics in the original)

Bertrand Russell's version is a sense-data theory of color:

> Let us give the name of 'sense-data' to the things that are immediately known in sensation: such things as colours, sounds, smells, hardnesses, roughnesses, and so on. We shall give the name 'sensation' to the experience of being immediately aware of these things. Thus, whenever we see a colour, we have a sensation of the colour, but the colour itself is a sense-datum, not a sensation. The colour is that of which we are immediately aware, and the awareness itself is the sensation. It is plain that if we are to know anything about the table, it must be by means of the sense-data – brown colour, oblong shape, smoothness, etc. (1912: 5)

According to Russell, colors are non-physical, non-sensational sense data that are objects of perception, and that are means by which one can have inferential knowledge about material objects.

The anti-objectivist view can be spelled out as a third-realm view of color in a triple-realms metaphysics.

Seventh, the anti-objectivist view can be spelled out as a trans-world property view of colors, which claims that colors are trans-world properties that material objects might have in some counterfactually possible worlds, rather than properties of material objects in the actual world. For instance, Chalmers (2006) defends the view that perfect colors are Edenic properties in Eden (which is a metaphysically possible world). Specifically, he claims that (i) perfect colors are Edenic properties attributed to objects in the content of color experience, (ii) Eden is supposed to be a metaphysically possible world, and (iii) a color experience is (perfectly) veridical iff the Edenic colors are instantiated in Eden:

For (i), "[p]erfect colors are attributed in Edenic contents … Perfect colors play certain further core roles …: we seem to be acquainted with their intrinsic nature in color experience, and the perfect colors arguably stand in relevant intrinsic structural relations to each other …" (2006: 47).

For (ii), "Eden does not exist, but could it have existed? That is, is there a possible world in which there are perfect colors? Could God, if he had so chosen, have created such a world? I am not certain of the answer to this question. But I am inclined to say yes: there are Edenic possible worlds" (2006: 33). [56]

For (iii), "[t]he perfect veridicality of color experience would require that our world is an Edenic world, in which objects instantiate primitive color properties" (2006: 23).

The anti-objectivist view can be spelled out as a trans-world-property view of colors in a property dualist metaphysics.

Eighth, the anti-objectivist view can be spelled out as a nominalist view of color properties, which implies that an account of color properties is not an account of colors but rather an account of color predications. For instance, Johnston's (2018) version is as follows:

[56] Thesis (ii) relies on a realist notion of metaphysical modality, which is further based on the conceivability thesis which suggests that the mere conceivability of Eden in a conceptually coherent way implies the existence of Eden as a metaphysically possible world.

> [T]o be [predicatively] colored in this way or that is to appear to be pervaded by an expanse of the relevant color. To get more precise we must distinguish between episodic and standing appearances of pervasion; so to be colored red is to appear to be pervaded in the relevant part by some expanse of red, where "appear to be pervaded" is given its habitual rather than episodic reading. (2018: 181)

According to this view, to be colored is to look to be pervaded by a color expanse in a phenomenological sense. There is no need to assume the existence of color properties any more than that of color predications.

The anti-objectivist view can be spelled out as a nominalist view of color properties in any metaphysical framework that devalues the ontological status of properties, such as frameworks which involve a realist notion of colors as phenomenal kinds (in whatever sense) rather than properties.

Besides these eight approaches, the anti-objectivist view is also compatible with certain antitheoretical stances concerning colors [57] and is closely related to some general philosophical topics, like quietism and epistemic skepticism.[58] These are interesting and important topics; however, they will not be covered in our discussion.

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[57] For instance, the theoretical physicist Lee Smolin writes that "[w]hat's missing when we describe a color as a wavelength of light or as certain neurons lighting up in the brain is the essence of the experience of perceiving red. Philosophers give these essences a name: qualia. … The problem of qualia, or consciousness, seems unanswerable by science because it's an aspect of the world that is not encompassed when we describe all the physical interactions among particles" (2013: 269).

[58] For philosophical quietism, see Wittgenstein 1922. For a criticism of quietism regarding color, see Allen 2016. For epistemic skepticism regarding color, see Price 1932, Johnston 1992 and Pritchard and Ranalli 2021.

References

Allen, K. 2011. 'Revelation and the Nature of Colour', *Dialectica* 65: 153–176.

Allen, K. 2015. 'Hallucination and Imagination', *Australasian Journal of Philosophy* 93: 287–302.

Allen, K. 2016. *A Naïve Realist Theory of Colour.* Oxford: Oxford University Press.

Allen, K. 2019. 'The Value of Perception'. *Philosophy and Phenomenological Research* 100 (3): 633–656.

Armstrong, D. M. 1968. *A Materialist Theory of the Mind*. London: Routledge.

Armstrong, D. M. 1993. 'Reply to Campbell'. In J. Bacon, K. Campbell and L. Reinhardt (eds.), *Ontology, Causality and Mind*, Cambridge, MA: Cambridge University Press, 268–273.

Armstrong, D. M. 1997. *A World of States of Affairs*. Cambridge: Cambridge University Press.

Armstrong, D. M. 1999. *The Mind–Body Problem: An Opinionated Introduction.* Westview Press.

Asimellis, G. 2020. *Wave Optics*. Bellingham: SPIE Press.

Berkeley, G. [1709] 1993. *Essay Towards a New Theory of Vision*. In Michael R. Ayers (ed.), *Philosophical Works. Including the Works on Vision*, London: Everyman.

Block, N. 1990. 'Can the Mind Change the World?' In G. S. Boolos (eds.), *Meaning and Method: Essays in Honor of Hilary Putnam*, New York: Cambridge University Press, 137–170.

Block, N. 2003. 'Mental Paint'. In M. Hahn and B. Ramberg (eds.). *Reflections and Replies: Essays on the Philosophy of Tyler Burge*. Cambridge, MA: MIT Press, 165–200.

Boghossian, P., and Velleman, J. D. 1989. 'Colour as a Secondary Quality'. *Mind* 98, 81–103.

Broackes, J. 1992. 'The Autonomy of Colour'. Reprinted in Byrne and Hilbert 1997a, vol. 1, 191–227.

Brown, D. H. 2006. 'On the Dual Referent Approach to Colour Theory'. *Philosophical Quarterly* 56(222): 96–113.

Brown, D. H. 2022. 'Colour Variation without Objective Colour'. *Philosophy and the Mind Sciences*, vol. 3, 17.

Builes, D. Forthcoming. 'Modal Idealism'. In U. Kriegel (ed.), *Oxford Studies in Philosophy of Mind*, vol. 4. Oxford: Oxford University Press.

Byrne, A. 2001. 'Intentionalism Defended'. *Philosophical Review* 110: 199–240.

Byrne, A., and Hilbert, D. R. 1997. 'Colors and Reflectances'. In A. Byrne and D. R. Hilbert (eds.), *Readings on Color, vol. 1: The Philosophy of Color.* Cambridge, MA: MIT Press.

Byrne, A., and Hilbert, D. 2003. 'Color Realism and Color Science'. *Behavioral and Brain Sciences* 26: 3–21.

Byrne, A., and Hilbert, D. R. 2021. 'Objectivist Reductionism'. In D. H. Brown & F. Macpherson (eds.), *The Routledge Handbook of Philosophy of Colour*. Routledge Taylor & Francis Group.

Campbell, J. 1993. 'A Simple View of Color'. In J. Haldane and C. Wright (eds.), *Reality, Representation, and Projection*. New York: Oxford University Press, 257–268.

Campbell, J. 2002. *Reference and Consciousness*. Oxford: Oxford University Press.

Campbell, J. 2005. 'Transparency vs. Revelation in Color Perception'. *Philosophical Topics*: 105–115.

Campbell, J. 2006. 'Manipulating Colour'. In T. Gendler and J. Hawthorne (eds.), *Perceptual Experience*. Oxford: Clarendon Press, 31–48.

Campbell, J. 2021. 'Does That Which Makes a Sensation of Blue a Mental Fact Escape Us?' In D. Brown and F. Macpherson (eds.), *The Routledge Handbook of Philosophy of Colour*. New York: Routledge, 408–420.

Chalmers, D. 1996. *The Conscious Mind: In Search of a Fundamental Theory*. Oxford: Oxford University Press.

Chalmers, D. 2006. 'Perception and the Fall from Eden'. In T. Gendler and J. Hawthorne (eds.), *Perceptual Experience*. Oxford: Oxford University Press, 49–125.

Chalmers, D. 2019. 'Idealism and the Mind–Body Problem'. In W. Seager (eds.), *The Routledge Handbook of Panpsychism*. New York: Routledge, 353–373.

Chevreul, M. 1839. *The Principles of Harmony and Contrast*, edited by F. Birren. West Chester, PA: Schiffer, 1987.

Chirimuuta, M. 2015. *Outside Color: Perceptual Science and the Puzzle of Color in Philosophy*. Cambridge, MA: MIT Press.

Clark, A. 2000. *A Theory of Sentience*, Oxford: Oxford University Press.

Cohen, J. 2008. 'Colour Constancy as Counterfactual'. *Australasian Journal of Philosophy* 86: 61–92.

Cohen, J. 2009. *The Red and the Real*. Oxford: Oxford University Press.

Danne, N. 2020. 'How to Make Reflectance a Surface Property'. *Studies in History and Philosophy of Modern Physics* 70: 19–27.

Dretske, F. 1995, *Naturalizing the Mind*. Cambridge, MA: MIT Press, Bradford Books.

Dretske, F. 2000, *Perception, Knowledge and Belief*. Cambridge: Cambridge University Press.

Dummett, M. 1979. 'Common Sense and Physics'. In G. F. MacDonald (ed.), *Perception and Identity*. London: MacMillan, 1–40.

Dummett, M. 1991. *The Logical Basis of Metaphysics*. Cambridge, MA: Harvard University Press.

Dummett, M. 1993. *The Origins of Analytical Philosophy*. Cambridge MA: Harvard University Press.

D'Zmura, M. 1992. 'Color Constancy: Surface Color from Changing Illumination'. *Journal of the Optical Society of America*. *Optics and Image Science* 9: 490–493.

Fairchild, M. D. 2013. *Color Appearance Models*. John Wiley & Sons, Ltd.

Finlayson, G. D. 1996. ‘Color in Perspective’. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 18(10): 1034–1038.

Fish, W. 2009. *Perception, Hallucination, and Illusion*. Oxford: Oxford University Press.

Feynman, R. 1988. *QED*. Princeton: Princeton University Press.

Feynman, R. 2013. *The Feynman Lectures on Physics, volumes I&II.* The Feynman Lectures Website (https://www.feynmanlectures.caltech.edu/I_toc.html), September 2013.

Funt, B. V., Drew, M. S., and Ho, J. 1991. ‘Color Constancy from Mutual Reflection’. *International Journal of Computer Vision* 6: 5–24.

Foster, J. 2008. *A World for Us*. Oxford: Oxford University Press.

Gauch, H. G. Jr. 2003. *Scientific Method in Practice*. Cambridge: Cambridge University Press.

Germer, T. A., Zwinkels, J. C., and Tsai, B. K. (eds.). 2014. *Spectrophotometry: Accurate Measurement of Optical Properties of Materials.* Waltham, MA: Elsevier Inc.

Gert, J. 2008. ‘What Colors Could Not Be: An Argument for Color Primitivism’. *Journal of Philosophy* 105: 128–157.

Gert, J. 2017. *Primitive Colors: A Case Study in Neo-Pragmatist Metaphysics and Philosophy of Perception*. Oxford: Oxford University Press.

Gert, J. 2021. ‘Primitivist Objectivism’. In D. Brown and F. Macpherson (eds.), *The Routledge Handbook of Philosophy of Colour*. New York: Routledge, 299–310.

Griffiths, D. J. 2024. *Introduction to Electrodynamics.* Cambridge: Cambridge University Press.

Goethe, J. W. von 1810. *Theory of Colours*, translated by C. L. Eastlake. Cambridge, MA: MIT Press, 1970; original English publication, 1840.

Gow, L. 2017. ‘Colour Hallucination: A New Problem for Externalist Representationalism’. *Analysis* 77(4): 695–704.

Hardin, C. L. 1988. *Color for Philosophers: Unweaving the Rainbow*. Indianapolis: Hackett.

Harman, G. 1990. ‘The Intrinsic Quality of Experience’. *Philosophical Perspectives* 4: 31–52.

Hecht, E. 2017. *Optics*. Pearson Education Limited.

Helmholtz, H. 1954. *On the Sensations of Tone as a Physiological Basis for the Theory of Music*, A. J. Ellis (trans.), Originally published in 1856. New York: Dover Publications.

Hering, E. 1878. ‘Zur Theorie der Farbenmischung’. *Crelle's Journal of Pure and Applied Mathematics*, 93, 1–21.

Hilbert, D. 1987. *Color and Color Perception*. Stanford, CA: Center for the Study of Language and Information.

Hildebrand, T. 2016. ‘Two Types of Quidditism’. *Australasian Journal of Philosophy* 94(3): 516–532.

Hoffman, D. 2001. ‘The Data Problem for Color Objectivism’. *Consciousness and Cognition* 10: 74–77.

Huygens, C. 1690. *Traité de la lumière*. Leiden: Pieter van der Aa.

Jackson, F. 1996. 'The Primary Quality View of Color'. *Philosophical Perspectives* 10 (Metaphysics): 199–219.

Jackson, F. 1998. *From Metaphysics to Ethics*. Oxford: Oxford University Press.

Jackson, F. 2019. 'How to Be an Objectivist about Colour'. *Phenomenology and the Cognitive Sciences* 18: 819–831.

Jackson, F. 2020. 'Learning from What Color Experiences Are Good For'. *The Harvard Review of Philosophy* 27: 49–58.

Johnston, M. 1992. 'How to Speak of the Colors'. *Philosophical Studies* 68: 221–263.

Johnston, M. 2018. 'Sensory Disclosure: Neither a Propositional, Nor a Factive, Attitude'. In A. Grzankowski and M. Montague (eds.), *Non-Propositional Intentionality.* Oxford: Oxford University Press, 152–191.

Judd, D. B. 1952. *Color in Business, Science, and Industry*. John Wiley & Sons, Inc.

Judd, D. B., and Wyszecki, G. 1975. *Color in Business, Science and Industry*. John Wiley & Sons, Inc.

Kastrup, B. 2018. 'The Universe in Consciousness'. *Journal of Consciousness Studies* 25(5–6): 125–155.

Keegan, H. J. 1939. 'Preparation and Colorimetric Properties of a Magnesium Oxide Reflectance Standard'. *National Bureau of Standards Letter Circ*., LC-547.

Kripke, S. 1980. *Naming and Necessity*. Oxford: Blackwell.

Gow, L. 2017. 'Colour Hallucination: A New Problem for Externalist Representationalism. Analysis 77: 695–704.

Levin, J. 2000: 'Dispositional Theories of Color and the Claims of Common Sense'. *Philosophical Studies* 100(2): 151–174.

Lewis, D. 1970. 'How to Define Theoretical Terms'. *Journal of Philosophy* 67: 427–446.

Lewis, D. 1973. *Counterfactuals*. Cambridge: Harvard University Press.

Lewis, D. 1986. *On the Plurality of Worlds*. Basil Blackwell.

Lewis, D. 1997. 'Naming the Colors'. *Australasian Journal of Philosophy* 75: 325–342.

Lewis, D. 2004. 'Void and Object'. In J. Collins, N. Hall and L. A. Paul (eds.), *Causation and Counterfactuals.* Cambridge MA: MIT Press, 277–290.

Logue, H. 2012. 'Why Naïve Realism?' *Proceedings of the Aristotelian Society* 112: 111–137.

Lycan, W. 1996. *Consciousness and Experience*. Cambridge MA: MIT Press.

Lycan, W. 2001. 'The Case for Phenomenal Externalism'. *Philosophical Perspectives* 15: 17–35.

Mackie, J. L. 1973. *Truth, Probability and Paradox.* Oxford: Oxford University Press.

Mackie, J. L. 1977. 'Dispositions, Grounds and Causes'. *Synthese* 34: 361–370.

Maloney, L. T., and Wandell, B. A. 1986. 'Color Constancy: A Method for Recovering Surface Spectral Reflectance'. *Journal of the Optical Society of America: Optics and Image Science* 3: 29–33.

Martin, M. G. F. 2002. 'The Transparency of Experience'. *Mind and Language* 4: 376–425.

Matthen, M. 1988. 'Biological Functions and Perceptual Content'. *Journal of Philosophy* 85: 5–27.

Matthen, M. 2018. 'Ephemeral Vision'. In T. Crowther and C. M. Cumhaill (eds.), *Perceptual Ephemera.* Oxford Scholarship Online.

Maund, B. 1995. *Colours: Their Nature and Representation*. Cambridge: Cambridge University Press.

Maund, B. 2006. 'The Illusory Theory of Colours: An Anti-realist Theory'. *Dialectica* 60(3): 245–268.

Maund, B. 2011. 'Color Eliminativism'. In Nolan 2011a: 362–385.

Maxwell, J. C. 2010. *The Scientific Papers of James Clark Maxwell*, *volumes 1–2.* W.D. Niven (ed.). Cambridge: Cambridge University Press.

McDowell, J. 1985. 'Values and Secondary Qualities'. In T. Honderich (ed.), *Morality and Objectivity*. London: Routledge, 110–129.

McGinn, C. 1983. *The Subjective View*. Oxford: Clarendon Press.

McGinn, C. 1996. 'Another Look at Colour'. *Journal of Philosophy* 93: 537–553.

McKitrick, J. 2003. 'A Case for Extrinsic Dispositions'. *Australasian Journal of Philosophy* 81: 155–174.

McKitrick, J. 2004. 'A Defence of the Causal Efficacy of Dispositions'. *Sats: Nordic Journal of Philosophy* 5: 110–130.

McKitrick, J. 2005. 'Are Dispositions Causally Relevant?' *Synthese* 144: 357–371.

McLaughlin, B. 2003. 'Colour, Consciousness, and Colour Consciousness'. In Q. Smith and A. Jokic (eds.), *Consciousness: New Philosophical Perspectives*. Oxford: Oxford University Press, 97–154.

Mendelovici, A. 2018. *The Phenomenal Basis of Intentionality.* New York: Oxford University Press.

Mizrahi, V. Forthcoming. 'Color Constancy Illuminated'. *Dialectica.*

Nakayama, K., Shimojo, S., and Ramachandran, V. S. 1990. 'Transparency: Relation to Depth, Subjective Contours, Luminance, and Neon Color Spreading'. *Perception* 19: 497–513.

Nassau, R. M. 1980. *The Physics and Chemistry of Color: The Fifteen Causes of Color*. New York: Wiley.

Newton, I. 1704. *Opticks.* London: Samuel Smith.

Nida-Rümelin, M. 2006. 'A Puzzle about Colors'. *Dialectica* 60(3): 321–336.

Palmer, S. 1999. *Vision Science*. Cambridge, MA: MIT Press.

Papineau, D. 2001. 'The Rise of Physicalism'. In B. Loewer and C. Gillett (eds.), *Physicalism and its Discontents*. Cambridge: Cambridge University Press, 3–36.

Pautz, A. 2006b. 'Can the Physicalist Explain Colour Structure in Terms of Colour Experience?' *Australasian Journal of Philosophy* 84: 535–564.

Pautz, A. 2021. 'How Does Colour Experience Represent the World?' In D. Brown and F. Macpherson (eds.), *The Routledge Handbook of Philosophy of Colour*. New York: Routledge, 367–389.

Peacocke, C. 1983. *Sense and Content*. Oxford: Oxford University Press.

Peacocke, C. 1984. 'Colour Concepts and Colour Experience'. *Synthese* 58(3): 365–381.

Peacocke, C. 2019. *The Primacy of Metaphysics*. Oxford: Oxford University Press.

Pelczar, M. 2019. 'Defending Phenomenalism'. *Philosophical Quarterly* 69: 574–597.

Price, H. H. 1932. *Perception*. Oxford: Oxford University Press.

Pinker, S. 2008. 'The Moral Instinct'. *New York Times Magazine* :32–58.

Pritchard, D and Ranalli, C. 2021. 'Mentalist Approaches to Colour'. In D. Brown and F. Macpherson (eds.), *The Routledge Handbook of Philosophy of Colour*. New York: Routledge, 42–51.

Rickabaugh, B., and Moreland, J. P. 2023. *The Substance of Consciousness*. Wiley-Blackwell.

Robinson, H. 2021. 'Mentalist Approaches to Colour'. In D. Brown and F. Macpherson (eds.), *The Routledge Handbook of Philosophy of Colour*. New York: Routledge, 342–351.

Robinson, H. 2022. *Perception and Idealism: An Essay on How the World Manifests Itself to Us, and How It (Probably) Is*. Oxford: Oxford University Press.

Rovelli, C. 2016. *Seven Brief Lessons on Physics*. New York: Riverhead Books.

Russell, B. [1912] 1967. *The Problems of Philosophy*. Oxford: Oxford University Press.

Russell, B. 1927. *The Analysis of Matter*. London: Kegan Paul.

Schrödinger, E. 1920. 'A Theory of Pigments of Maximum Luminous Efficiency'. *Proceedings of the Royal Irish Academy, Section A*, 37, 1–17.

Schrödinger, E. 1924. 'On the Origin of the Eye's Sensitivity Curves'. *Proceedings of the Royal Irish Academy, Section A*, 32, 53–69.

Schrödinger, E. 1925. 'On the Relationship between the Four-color and Three-color Theories'. *Proceedings of the Royal Irish Academy, Section A*, 33, 1–20.

Schrödinger, E. 1964. *My View of the World*. Cambridge: Cambridge University Press.

Sellars, W. 1963. 'Philosophy and the Scientific Image of Man', in *Science, Perception and Reality*. London: Routledge and Kegan Paul, 1–40.

Sharp, W. A. 2023. 'Spectral Reflectances and Commensurateness'. *Erkenntnis*: https://doi.org/10.1007/s10670-023-00762-8.

Shoemaker, S. 1991. 'Qualia and Consciousness'. *Mind* 100: 507–524.

Smart, J. J. C. 1975. ‘On Some Criticisms of a Physicalist Theory of Colors’. In C.-Y. Cheng (ed.), *Philosophical Aspects of the Mind–Body Problem*. University Press of Hawaii, 54–63.

Smolin, L. 2013. *Time Reborn: From the Crisis in Physics to the Future of the Universe*. New York: Houghton Mifflin Harcourt.

Stoljar, D. 2001. ‘Two Conceptions of the Physical’. *Philosophy and Phenomenological Research* 62(2): 253–281.

Stroud, B. 2000. *The Quest for Reality*. New York: Oxford University Press.

Swinburne, R. 2013. *Mind, Brain, and Free Will*. Oxford: Oxford University Press.

Thompson, E. 1995. *Colour Vision*. New York: Routledge.

Travis, C. 2004. ‘The Silence of the Senses’. *Mind* 113: 57–94.

Tye, M. 1994. ‘Qualia, Content, and the Inverted Spectrum’. *Noûs* 28: 159–183.

Tye, M. 1995. *Ten Problems of Consciousness: A Representational Theory of the Phenomenal Mind*. Cambridge, MA: MIT Press

Tye, M. 2000. *Consciousness, Color, and Content*. Cambridge, MA: MIT Press.

Tye, M. 2012. ‘Cohen on Color Relationism’. *Analytic Philosophy*.

Tye, M. 2014. ‘Transparency, Qualia Realism and Representationalism’. *Philosophical Studies* 170: 39–57.

Van Tuijl, H. F., and de Weert, C. M. 1979. ‘Sensory Conditions for the Occurrence of the Neon Spreading Illusion’. *Perception* 8(2): 211–215.

Watkins, M. 2010. ‘A Posteriori Primitivism’. *Philosophical Studies* 150: 123–137.

Webster, W. R. 2002. ‘Wavelength Theory of Colour Strikes Back: The Return of the Physical’. *Synthese* 132(3): 303–334.

Wilson, K. A. 2018. ‘Are the Senses Silent? Travis’s Argument from Looks’. In J. Collins and T. Dobler (eds.), *The Philosophy of Charles Travis: Language, Thought, and Perception.* Oxford Scholarship Online, 199–221.

Wittgenstein, L. 1922. *Tractatus Logico-Philosophicus*. Vienna: Otto Elsner.

Wyszecki, G., and Stiles, W. S. 1982. *Color Science: Concepts and Methods, Quantitative Data and Formulae*. John Wiley & Sons, Ltd.

Young, T. 1802. ‘On the Theory of Light and Colours’. *Philosophical Transactions of the Royal Society of London*, 92, 12–48.

Zeki, S. 1983. ‘Colour Coding in the Cerebral Cortex: The Reaction of Cells in Monkey Visual Cortex to Wavelengths and Colours’. *Neuroscience* 9: 741–765.