Color and Competence: A New View of Color Perception

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Abstract I have two main goals in this paper. My first goal is to sketch a new view of color perception. The core of the view can be expressed in the following two theses: (i) the overarching *function* of color vision is to enable and enhance the manifestation of relevant (species-specific) competences and (ii) color experiences are *correct* when they result from processing that directly and non-accidentally subserves the manifestation of such competences. My second goal is to show that the view can accommodate and account for a wide variety of color perceptual phenomena, including many problem cases. Importantly, the framework allows us to differentiate between two kinds of good cases of color perception: *ideal* cases where the demands of the relevant competences converge and *non-ideal* cases where the demands of the relevant competences diverge and clash.

Keywords Color perception · Competence · Correctness · Function · Color illusion

1 Introduction: why non-ideal cases matter from the start

Philosophical views of color are often inspired by the most straightforward cases of correct color perception. Call these "ideal" cases. An example of an ideal case would be the light bouncing off the surface of a ripe tomato causing a human trichromat with a normally functioning visual system to experience redness where the tomato is located in the visual field. There is nothing pathological about this case, nothing abnormal about the causal chain, and nothing too surprising about the percept itself.

We want a compelling story of what occurs when we perceive ripe tomatoes as red. At the same time, however, if we let ideal cases drive our inquiry, we run the risk of oversimplifying both our explanandum and our explanans. To see why this is, consider the following scenario. Say Adrian is a budding cartographer in search of an account of what makes a map good. She lives in a small desert, surrounded by just a handful of objects: some large rocks, a couple of houses, and a few cactus plants. When Adrian constructs her theory of good map-making, she doesn't consider any other kinds of environments, and comes to the conclusion that a good map (i) depicts all objects bigger than a grain of sand that a normal human perceiver situated in the mapped location could effortlessly perceive in good light, and (ii) accurately represents the spatial relations that obtain between those objects. It would be easy enough to create a map of this sort of Adrian's desert; one could even draw a grid in the sand and a corresponding grid on paper to find where objects should go (in this sense, Adrian's desert is an ideal terrain for map-making purposes). It is clear, however, that Adrian's standards are much too high for maps in general. Most perfectly good maps, no matter how detailed and carefully crafted, do not depict all objects bigger than a grain of sand.

The cartography example helps illustrate the dangers involved in heavy reliance on ideal cases when philosophizing about color perception. A good cartographer often has to compromise and make choices (say, by representing a tangle of trees with a single tree icon) in order to maximize the "goodness" of her maps. It is possible that color visual systems are like cartographers in this respect: when the perceptual situation isn't straightforward or ideal, the color visual system too might have to compromise. A compromise need not mean that the system isn't functioning well, or that the resulting color percept is somehow incorrect. It might just mean that we need a more sophisticated account of what makes color visual systems or specific instances of color perception successful.

I have two main goals in this paper. First, I wish to sketch a new view of color perception, one that isn't inspired by a narrow focus on ideal cases and one that takes into account the many ways in which color vision can be useful to perceiving organisms. Second, I wish to show how the view can account for a wide variety of color perceptual phenomena, including many problem cases. I proceed as follows: in §2 I introduce three desiderata for philosophical theories of color perception. In §3 I offer a first-pass characterization of my view: I suggest that color perception is *competence-embedded* in the sense that its overarching function is to enable or enhance the manifestation of relevant competences, and that color experiences are correct when they result from competence-enhancing processing. In §4 I show how this framework suggests a plausible explanation for some "textbook color illusions" by allowing us to distinguish between two kinds of good cases of color perception: ideal and non-ideal. In §5 I consider some pertinent objections and discuss ways in which we might refine and develop the view in response. In §6 I conclude that the view not only comes with a lot of explanatory purchase, but also allows us to uphold the powerful intuition that color visual systems are generally well-functioning systems that nevertheless sometimes fail.

2 Three desiderata for philosophical accounts of color perception

Before I characterize the view, it is helpful to consider some general features that we look for in a philosophical account of color perception. In this section I introduce three basic desiderata that are based on robust intuitions shared by many philosophers working on color. Though not wholly rigid and immutable, the desiderata mark a starting point for philosophizing about color perception and the sacrifice of any particular desideratum demands careful justification.

2.1 A view should not attribute widespread failure to (normally functioning) color visual systems

The first desideratum is based on a powerful intuition that color visual systems do their job fairly well. Humans tend to see color (or see *in* color) in ways that are consistent, coherent, and action-guiding. In addition, many other animals rely on color vision when they navigate, learn and memorize, and when they interpret or respond to their surroundings. It therefore seems intuitive to think that color visual systems are generally well-functioning systems.

A theory which entails widespread color misperception is in tension with this intuition.[1] An extreme example is provided by certain eliminativist philosophies of color (*e.g.* Hardin 1993, Maund 2006) which maintain that nothing in the external world is actually colored and that all color experiences are non-veridical. Implicit here is the idea that we experience color, think about color, and talk about color as if it were a stable (perhaps even mind-independent) property of physical objects, and that this is the kind of property that color would have to be in order for it to be *real*. Because we have good reasons to think that color is *not* this kind of a property, argues the eliminativist, we should conclude that all color experiences are illusory.[2]

Eliminativists face difficulties when it comes to explaining how color vision can be action-guiding and useful. If colors are illusory, then why do we experience them in the first place? How is a visual system that produces illusory experiences fitness-enhancing, and if it isn't, then why did such systems evolve in multiple phylogenetic lineages? Some eliminativists have argued that what is required for usefulness is just reliability, and not correctness per se (Mendelovici 2016), but this strategy makes it difficult to account for the difference between useful and "useless" reliably occurring color experiences. Seeing an apple as red against green foliage is arguably useful, whereas seeing the spinning Benham disc—an object which normally appears black-and-white when stationary—as colored doesn't seem to be. If both cases are instances of *reliably* occurring misperception, then what explains the difference? As long as the eliminativist has no convincing story to tell here, we have good reason to resist the view.

Most philosophers working on color today are color realists. But the first desideratum also puts pressure on many realist theories, especially the kind that attribute stable, fine-grained (determinate) colors to objects and propose that veridical color perception consists in accurate detection and representation of those colors (*e.g.,* Hilbert 1987, Tye 2000, Byrne and

[1] *E.g.,* Byrne and Hilbert admit that the entailment "that many of us misperceive unique greens" is an "unwelcome result" (1997, 274). See also Gert 2006.

[2] This kind of eliminativism accepts an objectivist treatment of color, but eliminativism about the colors of external objects is also consistent with the view that colors are instantiated by mental objects instead.

Hilbert 2003). The reason for this is simple: variation in color perception is systematic and extensive, and if we are to attribute *any* fine-grained colors to objects, it is difficult to escape the conclusion that most of our perceptual experiences deviate from the good case in which colors are correctly perceived.

2.2 A view should allow for instances of color visual system failure

The second desideratum is based on an equally powerful intuition that color visual systems do not *always* perform the way they are supposed to perform; that we *sometimes* see colors (or see *in* color) in ways that are confusing, inconsistent, or incorrect. We might hallucinate color or our color experiences could be distorted in some way. To accommodate this intuition, a philosophical view of color perception should allow for instances of incorrect color perception or at least explain our intuitions and ordinary discourse in some satisfactory way.[3]

If we think of color visual systems as having specific functions, and of color experiences as being correct when those functions are fulfilled, then incorrect color perception can be understood as color visual system failure. A theory of color perception should therefore allow for instances of color visual system failure where the system falls short of doing what it is *supposed* to be doing. It is fairly common to think of biological systems as having normative functions and of being susceptible of malfunction. A cardiovascular system is considered impaired when it fails to maintain adequate blood flow to different parts of the body and legs are considered to malfunction when they fail to support locomotion. Though there are divergent philosophical analyses of the nature of normative functions,[4] for my purposes here it suffices to say that the notion of normative function is deeply-rooted in both ordinary linguistic and scientific practice, and is commonly applied to color vision as well. That is, we quite naturally think of color visual systems as goal-directed systems outputting experiences that are evaluable relative to that goal.

Unsurprisingly, there are competing conceptions of the function of color vision (*e.g.,* Hatfield 1992, Hilbert 1992, Matthen 2005, Chirimuuta 2015), and different conceptions entail different degrees of color visual system failure. Most views uphold the basic intuition that some of our color

[3] This idea is commonly accepted by philosophers working on color and color perception. Boghossian and Velleman write that “seeing something as red is the sort of thing that can be illusory or veridical” (1989, 82n4). Chirimuuta suggests that it is strongly intuitive to think that color misperception occurs (2015, 179). Cohen maintains that the “idea that there are errors of color perception is so fundamental to our (naïve and scientific) thinking about the visual system that it would be very difficult to accept a theory of color that failed to sustain it” (2007, 349).

[4] The basic dividing line is between “Wrightian” (Wright 1973 and 1976) etiological analyses of function that appeal to natural selection (*e.g.,* Neander 2017) and Cummins-style (Cummins 1975) causal-role functional analyses which find normativity in the practices of the scientific community (*e.g.,* Hardcastle 2002).

experiences are incorrect, though there is a worry that some radically relativist views (McLaughlin 2003, Cohen 2009) fail to satisfy this desideratum. If colors are made relative to particular perceivers and particular perceptual circumstances, it is difficult to see how color perception could go wrong, except perhaps in instances of straightforward hallucination where nothing at all is really seen.

2.3 A view should allow us to evaluate and explain specific color experiences

The third desideratum asks that a philosophical view of color perception provide the means to evaluate the correctness of color experiences and that it suggest robust philosophical explanations for various kinds of color phenomena. The first part of this desideratum is straightforward enough. Arguably, any philosophical account of color perception worth its salt has some way of adjudicating whether a particular chromatic experience is correct or incorrect.[5] If the verdict is placed behind an epistemic veil of ignorance, it is unclear what work the notion of correctness can do.

If a view cannot unambiguously adjudicate *when* color experiences go wrong, it might also be less equipped to explain *why* they go wrong. This connects to the second part of the desideratum. Consider intrapersonal variation due to changes in chromatic context, for example. Suppose we have a theory which says that each uniform surface instantiates just one stable, fine-grained color. Suppose also that our target surface (*e.g.,* a paint sample card) gives rise to markedly different color experiences in some perfectly ordinary chromatic contexts (*e.g.,* when held against walls of different colors). Not only is it very difficult to determine which one of these chromatic experiences is the correct one, but the variation itself appears rather mysterious. It seems reasonable to ask why our perception should deviate from the good case in such a systematic (and potentially useful) manner, and if a view has nothing to say in response, that seems like a genuine weakness.

Whereas the first two desiderata concern the question of what philosophical views of color perception should entail about color perception on a more *general* level, the third desideratum concerns the application of views to *particular* instances of color perception. It is likely to be the most controversial desideratum out of the three, because it is not obvious that most philosophers think that their views should have illuminating things to say

[5] For example, one of the main objections to traditional dispositionalism—the view that colors are dispositions to cause certain kind of chromatic experiences in normal perceivers in standard conditions (*e.g.,* Levin 2000)—is that it cannot specify "normal" perceivers and "standard" conditions in any satisfactory, non-arbitrary manner (Hardin 1993). But this criticism doesn't just apply to dispositionalism, but to *all* theories that posit stable, determinate object colors (*e.g.,* Allen 2016, Campbell 1993, Byrne and Hilbert 2003). For criticism of the idea of unknowable color facts, see *e.g.* Cohen 2003.

about specific color perceptual phenomena.[6] At the same time, however, it seems relatively uncontroversial that a philosophical theory that helps us make better sense of our target phenomenon has at least some advantage over theories that leave us in the dark, all other things being equal.

3 The competence-embeddedness of color vision

With these desiderata in mind, I will now sketch my own account of color perception. I side with Akins (2001) in thinking that the primary function of color vision is to help organisms see *better* and see *more,* and I side with Chirimuuta (2015) in thinking that the correctness standards for color experiences are directly tied to this sort of usefulness. Chirimuuta calls her approach "perceptual pragmatism."[7] She rejects the notion that the correctness of a perceptual state is determined by its correspondence to states of affairs in the world, and she presents her alternative, utility-based epistemology as a *naturalized epistemology derived from the theoretical commitments of perceptual scientists* (2015, 101-110). I am sympathetic to both her general approach and her claim that we should evaluate color experiences in terms of usefulness (and not correspondence), but I worry that the notion of usefulness alone is too vague to do the kind of normative and

[6] Some philosophers appear to think that insofar as their view entails the illusoriness of a (type of) perceptual experience, then no other explanation for that (type of) experience is needed. For example, Tye suggests that simultaneous contrast effects in color perception are "illusions or normal misperceptions" that can be explicated in terms of "the workings of the visual system" (2000, 154-156), but doesn't himself attempt to explicate the issue any further.

[7] I consider myself to be directly building on the work of Akins and Chirimuuta here, but my view also shares similarities with certain other naturalistic, action-oriented accounts of color perception that link the correctness of color experiences to species-specific functions of color vision *(e.g.,* Thompson 1995, Hatfield 2003, Matthen 2005). For example, I am generally sympathetic to Matthen's thesis that sensory systems are "automatic sorting machines" that sort environmental objects "into classes according to how they should be treated for the purposes of physical manipulation and investigation" (2005, 8). That said, I think that Matthen's epistemology of color perception *overemphasizes* the role color vision plays in the building of a "stable record" of the properties of environmental objects. Matthen proposes, for example, that a color experience is incorrect if it disposes a perceiver to make mistaken inferences about the ripeness of fruit, *e.g.,* when the perceiver "misclassifies a particular fruit as pale green, though in fact it meets the physical specification of the sensory category, *yellow*" (*ibid.,* 208). I don't deny that we often use color-looks to make such inferences, but I maintain that an experience of a normally yellow-appearing fruit as pale green need not be incorrect, and that there can even be situations where experiencing the fruit this way constitutes the *best case scenario* for the perceiving organism. On the other hand, my approach has very little in common with certain other "pragmatist" views. One example is Gert's neo-pragmatist account which takes color language as its starting point and aims to explain "how and why we talk the way we do" (2018, 225). Whereas *perceptual* pragmatism often starts with the question of the function of color vision and looks to vision science for help, Gert's *linguistic* pragmatism starts with the question of the function of color terms in ordinary discourse.

explanatory work that we would ideally want our philosophical accounts of color perception to do. For this reason, I propose an analysis of usefulness in terms of *competence-embeddedness*. I start by explicating what I mean by "competence" (and "capacity"). I then explain what I consider to be the relevant kind of competences that directly embed color vision and allow us distinguish between correct and incorrect color experiences. Finally, I explain why I think that we should understand color perception as competence-embedded processing rather than as a full-fledged perceptual competence in its own right.

3.1 Competences and capacities

I find it helpful to think of perceptual activity as consisting in the exercise of perceptual *competences*. First, the notion of competence captures the apparent skillfulness of perception, *i.e.,* the idea that perceptual systems and processes are often reliable and well-functioning, and enable meaningful interactions with environments. That said, those readers who are suspicious of the idea of perception as reliable might prefer to think of perceptual activity as consisting in the exercise of perceptual *capacities* instead, since the notion of capacity is neutral on the question of reliability. Second, the notion of competence (and the notion of capacity) comes with conceptual resources to account for the differences in the aims of different kinds of perceptual systems and processes. In the case of vision, it allows us to distinguish between visual competences proper and the kind of visual processing that is merely competence-embedded. I take color vision to be an example of the latter.

There are different philosophical accounts on what competences (Greco 2007, Sosa 2015, Miracchi 2015) or capacities (Schellenberg 2018, Hornett 2021) are, but most of what I say in this section is going to be neutral between these accounts. For the sake of exposition, however, I'm going to briefly describe Sosa's view. To start, it appears that animals can have various kinds of aims. Some of these aims are purely epistemic or cognitive, some are behavioral or agential, and some are perceptual or perceptual-cognitive. Sosa maintains that we can assess all aim-involving performances for accuracy, adroitness, and aptness (2007, 22-23). When a performance is accurate, it achieves its aim. When a performance is adroit, it is produced by the exercise of the relevant competence. When a performance is apt, it is accurate because it is adroit, *i.e.,* the success of the performance manifests the competence of the performer. Sosa's competences are types of dispositions, *i.e.,* dispositions to succeed with aims, to perform well (2015, 26-27). For example, if Bailey is a competent cyclist, she possesses a cycling skill that allows her to succeed in (safely) riding a bicycle in a certain range of internal and external conditions. If her performance manifests her cycling competence, its success owes to her exercise of the competence. Similarly in the case of visual perception, Bailey's visual performance manifests visual competence(s) when the visual images she hosts "aptly correspond" to the object with which she perceptually interacts (see *ibid.,* 21).

Regardless of how we wish to understand competences/capacities, it is often intuitive enough to judge whether a competence/capacity is possessed. For example, it seems reasonable to think that many humans and bats are competent perceivers of distances, at least at the scale required for successful action. For my purposes here, it is important to emphasize that there are different ways to exercise a distance perception competence. Whereas some bats use biological sonar and auditory processing, humans tend to rely on visual processing. But if we go more fine-grained, we can see that even our own *visual* distance perception competence can be exercised in different ways. In low light, when only our rod photoreceptors are active, the exercise of our competence relies on luminance vision alone. But at higher levels of light most of us have an additional tool at our disposal—*color vision*.[8]

3.2 Relevant competences

To recap, I think that the aim of color vision is to help the perceiving organism see better in general, and that this aim determines the correctness standards for color experiences. I'm now ready to connect this idea to the notion of *competence-embeddedness*. When I say that color vision is competence-embedded (CE), I am making two interconnected claims:

> (CE-F) The overarching *function* of color vision is to enable and enhance the manifestation of relevant (species-specific) competences
>
> (CE-C) Color experiences are *correct* when they result from processing that directly and non-accidentally subserves the manifestation of relevant (species-specific) competences

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[8] Humans have two kinds of retinal photoreceptors: rods and cones. Both absorb light as a function of wavelength and intensity, but whereas the rods all have the same wavelength sensitivity, cones come in different types (normal human perceivers have three classes of cones with absorption maxima in the short-, medium-, and long-wavelength regions of the visible spectrum). Color vision requires the comparing of the activity of at least two classes of receptors with different wavelength sensitivities. Because there is only a single type of photoreceptor active in very low light, rod-mediated vision is achromatic. At higher levels of light, cones become active and their outputs "are combined at the post-receptor level in two different ways: one additive, giving rise to luminance signals with no information regarding the wavelength composition of light, and one subtractive, which preserves the latter and can thus be used for determining the color of objects" (Moutoussis 2015, 5).

CE-F is a claim about the *proper functioning* of the color visual system. [9] It specifies the normative function of color vision at its most fundamental and universal: color vision is *for* exercising competences, its job is to help an organism succeed with certain aims. The specific competences that color vision subserves might vary from species to species and it is an interesting empirical question what the species-specific relevant competences are and how they are organized. The claim I am making here is a more general one, however.

CE-C is an epistemological claim about the success conditions of color experiences. Though I think that the claim can be made for color *perceptions* more generally, my focus in this paper is on phenomenal experience. Ideally, a philosophical view of color perception tells us clearly and unambiguously when our color experiences are correct and when they are incorrect. My claim is that color experiences are correct when they result from processing that helps an organism manifest some relevant competence(s). When this is not the case, the experience can be said to be incorrect.

It seems natural to think that the competences relevant to the epistemology of color perception are competences that color vision *directly* and *non-accidentally* subserves. This condition helps keep various idiosyncratic interests and goals from making otherwise useless color experiences correct. For example, if I see a red afterimage which reminds me of my intention to buy apples, the experience of redness helps me manifest a competence in a purely accidental manner. My color visual system is not “aiming” to enhance or enable the manifestation of my competence to remember the items of my grocery list.

The competences that color vision directly and non-accidentally subserves are competences that color vision “aims” to subserve. At least some such competences are likely to have been fitness-enhancing in the animal’s evolutionary environment. Color vision (or a particular type of color vision, *e.g.,* a specific type of trichromacy) could then have been selected because it contributed to the manifestation of these fitness-enhancing competences. The analysis of the species-specific aims of color vision can therefore benefit from etiological analysis: we can ask how a specific kind of color visual system might have contributed to its own persistence by contributing to the persistence of the visual system as a whole and, ultimately, to the persistence of the organism as a whole. For example,

[9] I have chosen to discuss the “color visual system” as if were a unified entity and to lump together different kinds of processing that subserve different competences. Some readers might consider this an oversimplification and prefer instead to differentiate between two (or more) separate systems *within* color vision, *e.g.,* one system that computes chromatic contrast and another that computes (more or less constant) surface color representations (see *e.g.,* Akins and Hahn 2014, Moutoussis 2015). In the end, nothing I say here requires the adoption of the first conception, and those in favor of the multi-system conception can read me as suggesting that color vision consists in the operation of different systems that subserve different perceptual competences.

we can ask why trichromacy re-evolved in primates. If it evolved to aid scene segmentation and object recognition, for example, then we have good reason to think that scene segmentation and object recognition should be on our list of the relevant competences that embed color vision in trichromatic primates.[10]

That said, it is difficult to prove that primate trichromacy evolved to serve specific competences, and only those competences.[11] And even if this could be done, it might be that trichromacy has since acquired other functions, and that these functions have contributed to its maintenance and persistence. In other words, a particular type of color vision might have come to enhance competences that it didn't originally evolve to enhance.[12] To get a more comprehensive understanding of the functional profile of color vision in a given species or population, the perceptual pragmatist looks to uncover the *current* aims of color visual systems by paying close attention to what scientists are saying about the functional organization of the visual brain and about the role that color vision plays in the perceptual economy of the organism. Visual ecology can provide clues as to how animals use color vision to achieve important behavioral goals. Psychophysics can shed light on the rules and principles that govern color vision, and these can then be used to draw inferences about the aims of the color visual system in question. Neuroscience can reveal the involvement of the color visual system in different kinds of perceptual and cognitive tasks, and these findings can then be used to ground function attribution. In humans, empirical research has already helped identify a number of candidate competences; we have good reason to think that color vision functions to enhance and enable depth perception, distance perception, shape and form perception, shadow perception, figure-ground segregation and scene segmentation, object identification and re-identification, property identification, and memorization.[13]

The competences listed above are all ”ecological” competences that enable crucial animal-environment interactions by allowing animals to detect, locate, track, identify, categorize, and remember ecologically

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[10] On the origins and aims of primate color vision, see *e.g.,* Jacobs 1981, Mollon 1989, Dominy and Lucas 2001.

[11] We should, in general, exercise caution when proposing adaptive explanations for the number of cone types or the spectral tuning of those cones in a given species. As Chittka and Briscoe (2001) remind us, some sensory traits are better explained by phylogenetic constraint, evolutionary inertia, or random processes.

[12] Some etiological theorists require that proper functions reflect *recent* natural selection (*e.g.,* Godfrey-Smith 1994), while others appeal to the "continuing usefulness" of traits selected for specific purposes (*e.g.,* Schwartz 2002).

[13] See *e.g.,* Kingdom 2008, Shevell and Kingdom 2008, Troscianko et al. 1991, Smithson 2015, Tanaka et al. 2001, Paramei and Leeuwen 2016, Gegenfurtner and Rieger 2000, Moutoussis 2015. For a helpful overview, see Chirimuuta 2015, chapter 4. Vision scientists themselves often engage in function attribution and seem sensitive to the distinction between the kind of perceptual phenomena that plausibly reflect the proper functions of color vision and the kind of perceptual phenomena that are mere by-products of the mechanisms of color vision.

important objects, object properties, and relations. To be sure, color vision can play a part in the manifestation of other kinds of competences as well. For example, paying close attention to the chromatic appearance of a painting could have helped ascertain its value in fifteenth century Italy (see Baxandall 1988). But note that color vision could only help manifest such painting appraisal competence by first enhancing or enabling the manifestation of a competence to identify the use of certain expensive pigments, such as lapis lazuli-derived ultramarine. In other words, color vision could only help manifest the non-ecological competence indirectly, via the manifestation of a more basic ecological competence: property identification.[14]

What ultimately determines the correctness of a particular color experience, then, is the relevant species-specific ecological competences. As the red afterimage example shows, sometimes color-involving experiences can be useful without being correct. This statement can now be understood as referring to cases where color vision is useful without helping the perceiver manifest any relevant ecological competences.

3.3 Case study: the color visual system and figure-ground segregation

I will now consider an example of a relevant ecological competence in humans: figure-ground segregation. This is an essential step in visual processing in which individual objects come to be perceived as figures bounded by closed contours. Separating objects from backgrounds requires that a border shared by two visual regions be assigned to one of those regions, producing a percept of a shaped object located closer to the perceiver.[15]

Figure-ground segregation is rarely a conscious aim. It tends to be an automatic process to which we rarely pay attention unless it becomes challenging for some reason, *e.g.,* due to poor visibility. This is not to say that the problem is trivial. A number of features of natural scenes make it a challenging task: objects are often partially occluded, and scenes tend to be cluttered and noisy, *e.g.,* incident light can create false boundaries and certain types of camouflage can make objects blend with their backgrounds. And so, when assigning boundaries to objects, visual systems often have to rely on a number of factors ranging from low-level image-based cues (convexity, symmetry, small area, closure, top-bottom polarity etc.) to higher-level factors such as past experience.[16]

[14] Of course the ability to recognize ground-up lapis lazuli from the way it chromatically appears likely had nothing to do with the evolution of color vision in humans and other primates. But this ability is a special case of a more general, ecologically-relevant ability to recognize properties (being ripe, being angry etc.) from the way things chromatically appear (red etc.).

[15] These are objects at the relevant, species-specific level of description. For humans, this means things like apples, tables, and mosquitoes.

[16] For a review, see Peterson 2015.

Phenomenologically speaking, meaningful objects are defined both by their boundaries and by their surfaces. When I perceive a cat napping on an armchair, I perceive the boundary of the cat as a discontinuity in space, and the surface of the cat as a continuous region to which the boundary belongs. Some have suggested that boundary detection alone is sufficient for figure-ground segregation (*e.g.,* Biederman 1987), but there exists compelling evidence that figure-ground segregation is influenced by, and sometimes requires, surface representation (see *e.g.,* Smithson 2005, Yamagishi and Melara 2001). An interesting question for my purposes is *if* and *how* color vision contributes to figure-ground segregation. Does it contribute to surface representation, to boundary representation, to neither, or to both?

There is plenty of evidence of the involvement of the color visual system in surface representation (see *e.g.,* Dresp-Langley and Reeves 2014, Palmer and Brooks 2008). De Valois and Switkes find asymmetric interaction between (isoluminant) chromatic stimuli and (isochromatic) luminance stimuli; whereas chromatic gratings appear to profoundly mask luminance gratings, the converse is not true. The authors offer an ecological explanation: because there normally exists a great deal of luminance noise in our environments, "it would be an organism's benefit to segregate objects from the backgrounds on the basis of color differences rather than luminance differences" (1983, 17). That said, the received view in perceptual psychology and neuroscience has been that contour perception is achieved by the luminance system. For example, Rogers-Ramachandran and Ramachandran (1998) propose that an "essentially color-blind," fast-acting system extracts visual contours, whereas a slower system computes surface colors. But this suggestion now appears oversimplified, and a growing body of evidence points to the important role that color vision plays in the perception of object boundaries.[17] Neuroscientists have identified "color-sensitive," orientation-tuned neurons in the primate visual cortex that respond to pure chromatic gratings (see Shapley et al. 2014 for a review)[18] and psychophysicists have confirmed the contributions of color vision to primate contour perception (see *e.g.,* Moutoussis 2015, Hansen and Gegenfurtner 2017).

All in all, we have very good reason to think that our color visual system helps with figure-ground segregation by contributing to both contour representation and surface representation. That both the color visual system

[17] When it comes to boundary computations, the cells in the luminance system respond to luminance edges even in the absence of chromatic contrast, and the cells in the color visual system respond to (certain kinds of) chromatic edges even in the absence of luminance contrast. That said, the luminance system and the color visual system need not be thought of as being completely independent and modular. There is likely to be interaction between the two and the systems might even share some neural resources in the visual cortex (see *e.g.,* Shapley et al. 2014, 577; Moutoussis 2015, 6).

[18] Garg et al. (2019) suggest that even the majority of color-*preferring* neurons in the primary visual cortex might be strongly tuned for orientation.

and the luminance system should enhance and enable the manifestation of this very important perceptual competence is hardly surprising. As Akins and Hahn remind us, "when a sensory system guides the real-time behaviour of an organism, any information that makes its visual computations faster, cheaper, or more reliable is ripe for selection" (2014, 139). In other words, the improved efficiency and reliability of such computations alone seems to explain why color visual systems exist in many different types of animals.

That said, we still need to address one important question. So far I have suggested that the primary goal of color visual systems is to enable and enhance the manifestation of relevant competences. But why should we think that color perception is merely competence-embedded, and not a perceptual competence in its own right? In other words, why isn't the *primary* aim of color vision to see colors, and its competence-enhancement role merely secondary?

3.4 Why color perception is not a competence

To argue that color perception is competence-embedded in my sense is to argue that color vision aims to enable and enhance the manifestation of relevant competences, and that *this enhancement function fully determines its success conditions.*

If color perception were itself a competence/capacity, then what would be its function? A natural answer is that the function would be to perceive (to detect, represent, and/or successfully engage with) the chromatic properties of our environments. This, in turn, suggests that the success conditions of color perception would have to do with *correspondence:* a color experience would be successful if it matched the chromatic property instantiated by the object (and if the success resulted from an exercise of a competence/capacity), and unsuccessful if it didn't.

This fits in well with how Schellenberg defines the function of a perceptual *capacity*. She suggests that "the function of a perceptual capacity C_α is to discriminate and single out mind-independent particulars $\alpha_1, \alpha_2, \alpha_3, \ldots \alpha_n$, that is, particulars of a specific type" (2018, 34). In the case of color perception, this would mean that there had to exist some stable objective chromatic properties for the color visual system to discriminate and single out. For example, the function of the capacity to perceive red would be to discriminate and single out red particulars in the world. This function would be fulfilled in veridical perception, whereas the same capacity would be unsuccessfully employed in the case of non-veridical perceptual experience (see *ibid.,* 43).[19]

[19] The idea is that when we hallucinate a red particular, there doesn't *really* exist a red particular to be discriminated and singled out. When our perception of a given particular as red is illusory, the particular exists but does not instantiate the property of redness. In both cases, then, there is a lack of correspondence between the perceiver's perceptual state and the state of the world.

Miracchi (2017) offers an alternative account of perceptual competences. She does not require that the properties we engage with be objective and mind-independent, but the idea of stability plays a role in her approach as well. This is evident in her requirement that "appropriate regularities" involving the agent and the perceived object obtain, and that "perceptual competences reliably issue in cases of perceiving things as they are" (2017, 645, 650). In the case of color perception, a natural way to understand such regularities would be to link a particular (type of) object surface to a particular (type of) chromatic experience in a given perceiver. For example, the manifestation of a competence to perceive things to be red would require that the object in question were, in fact, red (*i.e.*, reliably linked to red experiences in that perceiver). Perceptual illusion, on the other hand, would occur when an object reliably linked to, *say*, blue experiences were experienced as red instead (see *ibid.,* 663).

Though very different, Schellenberg's and Miracchi's accounts both emphasize some sort of a stable link between perceptual experiences and the objects being perceived, and conceptualizing color perception as a competence/capacity seems to naturally go with an emphasis on the stability and constancy of color experience.[20] The problem with this is that color visual systems also appear to have "aims" that do not require such stability; the contribution of the color visual system to contour perception is a case in point. Notice also that variation in color perception is systematic and rife, even on an intrapersonal level. Our phenomenal experiences of the colors of surfaces (etc.) are influenced by such factors as lighting conditions, chromatic contexts, viewing angles, and viewing distances. Though this kind of variation could be conceptualized as color visual system failure, it is often *useful* to the perceiver. For example, if a ripe, normally red-appearing apple looks even redder when surrounded by green foliage, this increases the conspicuousness of the apple in that specific context. And if our perceptual engagement with a target smooths out some of its (physical) surface variation through the process of color assimilation, this plausibly enhances the perceived figureness of the object. Because these kinds of effects are incredibly common in everyday perception, and because plausible ecological explanations for the effects exist, it seems perfectly reasonable to assume that the effects might reflect the aims of color systems and feature in perfectly good cases of color perception.

Recall that empirically-oriented philosophers like Akins contend that color vision is not for seeing colors or for seeing things as colored, but for seeing better in general. If you add to this Chirimuuta's view that the success standards of color experiences are entirely utility-based, then the resulting views have no use for the kind of regularities between objects and perceptual

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[20] One could attempt to formulate a radically relativist competence account of color perception by proposing that the appropriate regularities obtain between particular perceptual agents, object surfaces, and *particular perceptual circumstances*. Though this would eradicate the need to posit stable object color, it would also dilute the notion of a perceptual competence.

experiences that competence/capacity accounts of color perception rely on to get off the ground. The best way to make a competence framework compatible with this sort of pragmatism is to hold that color perception is competence-embedded, rather than a competence itself. But this is precisely why the notion of competence is so useful. It helps us make sense of the idea that not all the properties presented to us in visual experience are on a par; some are *what* we (can) competently perceive, others are *how* we (can) competently perceive.

4 "Textbook color illusions" as test cases

"Textbook color illusions" are images created to illustrate systematic color perceptual phenomena. The relevant phenomena are often subtle enough to escape our attention in everyday contexts, and the images are designed to increase the magnitude of the effects to make them more noticeable. In this section I will use two such "illusions" to test the explanatory potential of CE. Both are examples of color induction where a neighboring region induces a shift in the perceived chromaticity of a target region. I suggest that the perception of these and many other textbook illusions constitute paradigmatic "non-ideal" cases of color perception where the demands of the relevant competences clash.

4.1 Clashing competences

So far I have suggested that the function of color vision is to enable and enhance the manifestation of relevant competences. Now I want to employ the notion of competence-embeddedness to distinguish between two kinds of successful or ”good” cases of color perception: *ideal* and *non-ideal.*

I start by proposing that competences impose certain kinds of "demands" on the color visual system. An object re-identification competence demands that the experienced color of the object remain relatively *constant* in different perceptual situations. Other competences, such as figure-ground segregation, demand that the color of a particular object be experienced as sufficiently *different* from the colors of the neighboring regions. In many good cases of color perception, the demands of the relevant competences line up, and color vision can simultaneously fulfill its enhancement function with respect to all of them. We can call such cases ”ideal.” For example, seeing a ripe Red Delicious apple as red can simultaneously enhance figure-ground segregation, object (apple) recognition, property (ripeness) identification, and so on. [21]

[21] Perceivers can, of course, fail to manifest perceptual competences for various reasons. I might mistake a tomato for an apple, *i.e.,* fail to exercise my object (tomato) identification competence, even if my color visual system is doing everything right and the "demands" of the competences line up.

In some other good cases, however, the demands of the relevant competences diverge and clash. We can call such cases “non-ideal.” Non-ideal good cases differ from “bad” cases of color perception in that in the non-ideal cases color vision directly and non-accidentally enhances or enables *at least one* relevant competence, whereas in the bad cases color vision doesn’t help the organism manifest *any* of the relevant competences.[22] Consider the example of negative afterimages. Suppose that you stare at a blue patch for a prolonged period, allowing your cones enough time to adapt to the stimulation and lose sensitivity. If you then turn your gaze to a white surface, a yellow patch appears. The neural processing that results in the experience of yellowness isn’t useful to you and doesn’t help you manifest any relevant competences.[23] In non-ideal good cases, on the other hand, the perceptual circumstances are such that the color visual system in forced to “choose” between the conflicting demands of the relevant competences. This does not mean that the system fails, but that it fulfills its function *to the extent possible under those circumstances.* Recall the analogy of the cartographer who has to choose what to represent in a map and how to represent it. Like the cartographer, the color visual system has to sometimes choose how to best serve perception and action.[24] [25]

4.2 Color assimilation: watercolor effect

[22] The distinction between ideal and non-ideal good cases has nothing to do with the appeals that some philosophers make to “ideal conditions” in which the true colors of object surfaces are veridically perceived by normal perceivers. Under my view, color experiences are correct in both ideal and non-ideal cases, and the distinction is merely meant to capture the difference between perceptual situations where the demands of the relevant competences clash and situations where no such clash occurs.

[23] In the afterimage case the color visual system is engaged and a chromatic experience results. That said, we could plausibly extend the notion of color visual system failure to situations where the relevant kind of processing simply doesn’t take place. In very low light, the visual perception of contours, objects, and scenes relies solely on achromatic rod vision, with no help from color vision. From the point of view of CE, any instance of visual perception in which color vision fails to be useful can be considered a ”bad” case of color perception. This is because the role of color vision in the perceptual economy of the organism is understood purely in terms of enhancement. When such enhancement takes place, the color system fulfills its function, and we have a good case of color perception. When enhancement doesn’t take place, we have a bad case of color perception. Just as a respiratory system can fail to fulfill its function due to some internal condition (*e.g.,* pulmonary embolism) or some external condition (*e.g.,* the presence of high levels of carbon monoxide in the air), the color visual system, too, can fail to fulfill its function when the light levels are too low.

[24] “Choices” should be understood loosely as the rules that the color system either follows or instantiates.

[25] I mentioned earlier (in note 9) that some readers might prefer to think of color vision as dividing into multiple systems with different aims. Those readers can now read me as suggesting that in the ideal cases the demands of the competences converge and the different systems can fulfill their functions simultaneously (by coming up with the same answer, so to speak). In non-ideal cases, on the other hand, one of the systems is forced to cede precedence to another. Many thanks to an anonymous reviewer for pointing this out.

The perceived color of a target region sometimes shifts towards that of its neighbor and the chromatic contrast between the two regions is reduced (von Bezold 1876). This sort of assimilation of neighboring colors requires a particular kind of spatial organization; one way of inducing the effect is to intersperse small areas of color (Munker 1970). A particularly striking illustration of color assimilation is the so-called "watercolor effect," originally demonstrated by Pinna in 1987. In stimuli that produce this effect, adjacent regions are separated by two contiguous, differently colored boundary lines, one darker and the other lighter. The color of the lighter boundary then appears to spread to cover the enclosed area (Pinna et al. 2001, 2669). For example, in *Fig. 1* (both **a** and **b**), the color of the yellow line flanking the darker blue contour spreads to cover the area defined by the darker boundary. As Pinna (2005) notes, two separate effects are visible in watercolor illusions: coloration effect and figural effect. The coloration effect is the apparent assimilative color spreading; the figural effect is the figure-ground organization in which the colored area is seen as a figure against a background.

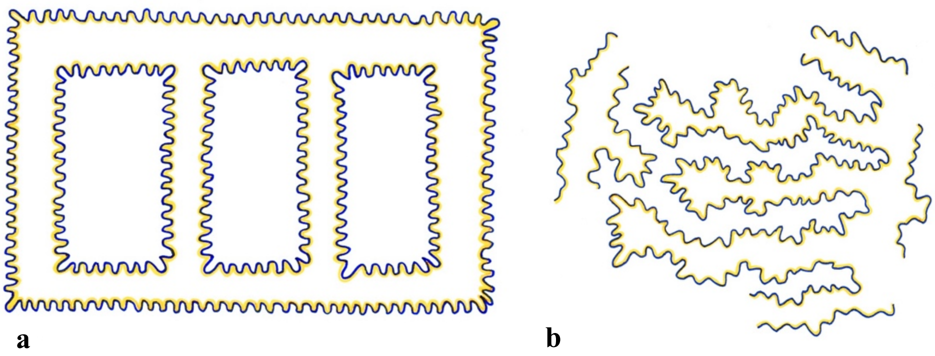

Fig. 1 A demonstration of "watercolor effect": the color of a yellow line flanking a darker contour of contrasting chromaticity appears to spread to cover the fully (**a**) or partially (**b**) enclosed area(s). Images are inspired by those found in Pinna et al., 2001

Watercolor illusions are *illusory* in that there isn't a three-dimensional figure where one is perceived; our experience imposes depth and volumetric impression onto a two-dimensional image. That said, illusory figural effects can provide clues as to how color vision subserves successful figure-ground segregation and object perception in more natural contexts. In this case it suggests that the visual system treats certain combinations of chromatic and achromatic edges as indicators of the presence of an object. In particular, it suggests that consistent edge color along a stretch of contour might be a figural cue that reliably correlates with objectness in our natural environments (von der Heydt and Pierson 2006, 337).[26]

[26] Pinna (2005) himself takes watercolor illusions to reveal a new principle of of perceptual grouping and figure-ground segregation that he calls the "the asymmetric luminance contrast

The figural effect in watercolor illusions is illusory, but how about the coloration effect? Does our color visual system fail when it presents some of the "white" areas in *Fig. 1* as faint yellow? Many philosophers would answer this question in the positive, and argue that *Fig. 1* tricks the system into producing an illusory experience. The problem is that if the watercolor effect reveals something about the way we normally compute and experience surface colors, then the color visual system failure might extend well into normal perception. More generally, if assimilation effects indicate color visual system failure, and if such effects are fairly commonplace, then much of our perceptual experience could turn out to be illusory.

One way to bring our perceptual experiences of *Fig. 1* into the confines of correct color perception is to take the radically relativist route and argue that the enclosed areas in *Fig.1* really *are* yellow for perceivers like us in circumstances in which we perceive them as yellow, barring interference with the normal functioning of the color visual system (see McLaughin 2003, Cohen 2009). In other words, if we relativize colors to particular perceivers and particular perceptual circumstances, we can maintain that the addition of certain types of bi-chromatic contours can sometimes literally change the color of a surface.

Though this strategy allows us to accommodate watercolor effects, it doesn't explain why we find these effects so puzzling. We seem naturally inclined to label watercolor effects illusory, and this inclination demands an explanation. It cannot just be that we are tricked into believing that the enclosed surface areas would produce these experiences in other contexts as well, *e.g.,* in the absence of the appropriate sort of bi-chromatic contours.[27] We can know about the watercolor effect and not hold any such beliefs, and still have the intuition that something about our faint yellow experience is a bit off. So what differentiates our experiences of watercolor illusions and our experiences of ripe Red Delicious apples? It seems that the relativist doesn't have much to offer here.

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principle." According to this principle, *ceteris paribus*, given a boundary and an asymmetric luminance contrast on both sides of the boundary, the region with the less abrupt luminance gradient is perceived as the figure, and the region with the more abrupt luminance gradient is perceived as the background (*ibid.,* 205). In *Fig. 1*, the luminance gradient is more abrupt where the dark contour directly meets the white background, and less abrupt where the dark contour meets the lighter contour which in turn meets the background. Though luminance contrast alone might be enough to bring about the figural effect, the coloration effect and the figural effects do seem to support and reinforce one another, as Pinna himself observes (see also von der Heydt and Pierson 2006, 334). In addition, Devinck et al. (2006) report that not only is a chromatic contrast between the two contours and between the contours and the background important for a *robust* watercolor effect, but that the effect can also be induced using equiluminant stimuli.

[27] Cohen explains the illusoriness of certain kinds of chromatic experiences by the non-veridicality of higher-level representations of the kind *surface x is orange to perceivers pretty much like me, in circumstances pretty much like those I normally encounter* (2007, 343). But we often find certain perceptual experiences puzzling when no such higher-level representations are involved.

The perceptual pragmatist starts by asking if the experiences elicited by the images in *Fig. 1* are useful to the perceiver. The enhancement of 3D figureness is not useful because it is illusory, but perhaps the coloration also helps the perceiver discriminate some spatial properties that the stimuli does in fact instantiate. It might, for example, help the perceiver discern and make sense of the 2D spatial structure of the image by having some of the regions appear white and others yellowish. In **a**, the coloration might help us more efficiently perceive three jagged rectangle shapes confined within a larger jagged rectangle shape. In **b**, the enhancement effect might be even more profound, because the spatial structure is more complex.

Though this kind of usefulness is arguably rather minimal, it is usefulness nonetheless. Though much of our spatial perception "in the wild" involves the perception of 3D shapes, 2D patterns and shapes can also carry ecological significance, *e.g.* in the case of the surface patterns of animals and plants. In the language of CE, it seems at least plausible that the coloration enhances the manifestation of a 2D shape perception competence, a competence that makes it easier for perceivers to discern and interpret images, patterns, and scenes. And so there need not be anything illusory about the yellowish tint.

That said, the coloration does *not* enhance the manifestation of many other relevant perceptual competences. In fact, it seems to make it *more difficult* for perceivers to exercise competences that demand constancy and similarity of experience. For example, if we were to remove the yellow contours from **a**, a naïve observer might deny that she was observing the same surface, if none of the regions no longer appeared yellow to her. But we should not blame this on the color visual system. The system is still doing what it is supposed to be doing, as long as it is making it easier for the perceiver to manifest at least one relevant competence. That it cannot enhance the manifestation of *all* the relevant competences is a consequence of stimulus properties that pit the demands of the competences against one another.[28]

4.3 Simultaneous color contrast: pink/grey petals

What looks yellow on an achromatic background might look greenish next to red and reddish next to green, and a normally red-appearing surface might look *even* redder next to green (Chevreul 1839/1861). This phenomenon is known as "simultaneous color contrast," and psychologist Akiyoshi Kitaoka has created many powerful illustrations. *Fig. 2* depicts cartoonish flowering plants against two differently colored backgrounds and is inspired by some

[28] Recall that textbook color illusions are usually designed to make certain kinds of perceptual effects more noticeable. In more ecologically realistic settings assimilation effects are likely to be less drastic, but also more useful.

of Kitaoka's works.[29] Though the plants are physically identical in both frames, they appear grey against the white background (**b**) and pink against the cyan background (**a**), at least to most normal human color perceivers. In what follows, I will focus on the two types of chromatic experiences elicited by the "petal" regions in the two frames: pink and light grey. The challenge for the philosopher is to explain which (if either) of these chromatic experiences is correct, and why.

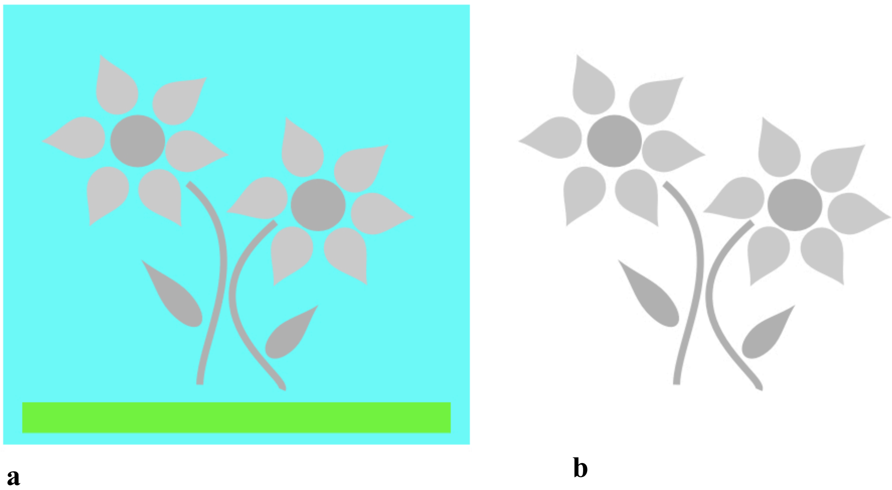

Fig. 2 A demonstration of simultaneous color contrast effect: physically identical flower shapes appear pink against cyan background (**a**) and grey against white background (**b**). Images are inspired by those found on Akiyoshi Kitaoka's website

Many philosophers argue that each physically homogeneous region instantiates just one determinate, fine-grained color to a particular type of perceivers (*e.g.,* Tye 2000, Byrne and Hilbert 2003). This entails that at most one type of chromatic experience of the petals can be correct (in that type of perceiver). The correctness question cannot be answered without privileging some specific perceptual conditions, and these include the color of the surround against which the target is viewed. It is doubtful that this specification can be done in a genuinely non-arbitrary manner.[30]

Though we can accommodate a great deal of perceptual variation by positing only *coarse-grained* stable colors (*e.g.,* Hatfield 1992 and 2003, see also Gert 2006), this move is unlikely to help here. Note that the motivation for views which attribute only coarse-grained colors to object surfaces (etc.) is often ecological and pragmatic: chromatic experiences can help perceivers identify objects and properties as long as those experiences stay within a certain range, *e.g.,* a ripe apple might appear one shade of red in daylight and another shade of red under incandescent lighting, and this is enough to help us recognize it as the same apple. An exact hue match is not required for

[29] The RGB values of the background in *Fig. 2* (**a**) are based on those used by Akiyoshi Kitaoka in the "Cherry blossom 2" section of his website.
[30] This point has been forcefully argued by Hardin 1993 and Cohen 2009.

such identification, but some degree of constancy is necessary. If the perceived color of the apple shifts from red to green, for example, the chromatic experience is no longer useful in this sense. The case with the petals seems analogous; our experiences simply do not fall within a range that would be conducive to such identification. This in turn suggests that the grey and pink experiences cannot both be correct, and that we again need some non-arbitrary way of privileging one of these perceptual variants over the other.[31]

Philosophers who attribute stable (fine-grained or coarse-grained) colors to surfaces therefore all seem to be in the same boat; they have to say that at least some instances of simultaneous color contrast constitute color visual system failure.[32] Letting go of the notion of stable color can help defend the color visual system against this charge, and one way to do this is to maintain that the petals really *are* grey when specific perceivers observe them against a white surround, just like they really *are* pink when the same perceivers observe them against a cyan background. But once again this sort of relativism seems ill-equipped to deal with the task of explaining the difference between textbook color illusions and more straightforward cases of correct color perception.

The perceptual pragmatist can make progress here by explaining the shifts in the perceived hue of the petals in terms of what is useful to the perceiver: seeing the petals as pink against the cyan background increases the contrast between the petals and the background, making the petals pop out. Though it is difficult to imagine what it would be like to experience the petals as achromatic grey against the cyan background, it seems reasonable to assume that the grey would more easily blend with the cyan, making it more difficult to segment and interpret the image. But this is just a beginning—we still need an account of the difference between seeing the petals as pink and seeing a ripe apple as red. If both experiences are useful, then why does it seem so natural to label one experience illusory and the other perfectly correct?

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[31] Hatfield (2003) suggests that the true coarse-grained colors that objects instantiate can be veridically perceived by species-specific normal perceivers in ecologically standard conditions. But ”ecologically standard conditions” cannot just refer to ecologically standard *lighting* conditions (*e.g.,* daylight for humans). If it did, then we couldn’t determine which color the petals in *Fig. 2 really* instantiate and we also couldn’t evaluate the correctness of the color experiences elicited by the image. On the other hand, specifying ecologically standard surround colors seems like a difficult task. Natural scenes instantiate a wide variety of different colors, including whites and brilliant cyans, and it seems arbitrary to rule some of them out as being ecologically non-standard.

[32] Views that posit stable fine-grained colors entail widespread color visual system failure (because hue shifts at the level of fine-grained colors are extremely common), whereas views that posit only coarse-grained colors can restrict such failure to special cases. But the latter views need to explain why perceptual variation due to simultaneous contrast is acceptable when it occurs within color types, but unacceptable when it crosses those types. This is particularly difficult if it turns out that color type-crossing perceptual variation is *useful* to the perceiving organism, since considerations of usefulness are often what often motivate such views to begin with.

CE can help fill in the gaps. Observing *Fig. 2* constitutes a non-ideal perceptual case where the relevant competences place divergent demands on the color visual system, whereas in the ripe apple case the demands of the relevant competences converge.[33] To understand how the demands diverge in the petals case, let us start by supposing that a normal human color perceiver is observing a printout of *Fig. 2*. Since she is observing a picture rather than a natural scene, the list of relevant perceptual competences is different from the apple case. There are no actual petals to be detected, identified or re-identified, just a flat image *depicting* petals against backgrounds of different chromaticities. Yet there are still relevant competences placing demands on the color system here. For example, the 2D shape perception competence demands that the regions with different physical properties be perceived as sufficiently different in hue, saturation and/or lightness. Where the petals are depicted against the white background in **b**, the achromatic luminance contrast alone seems to make them pop out (simultaneous luminance contrast might play some role here). In **a**, the luminance contrast is softer, and there is more of a danger of perceptual blending of the different regions. But in addition to luminance contrast, we now have chromatic contrast between the regions. By enhancing this contrast (and giving rise to an experience of pinkness), the color visual system can help ensure that the image is accurately segmented.

But once again this enhancement of the shape perception competence occurs at the expense of some other competences. If we secretly cut out a petal from **a**, hand it to our subject, and ask her if it is one of the petals she previously observed against the cyan background, she might well say no. This is because the petal no longer appears pink to her when removed from its original context. That is, seeing the petal as pink against the cyan background helps our subject manifest her shape perception competence, while at the same hindering the manifestation of her re-identification competence.

CE entails that the apple case and the petal case are both instances of successful, correct color perception. It also entails that there is a clear difference between the two: in the apple case the color visual system can fulfill its competence-enhancement function more fully because the demands

[33] Imagine a human color normal viewing a ripe Red Delicious against green foliage. Figure-ground segregation and object perception competences "demand" that the apple be perceived as chromatically different from the surrounding foliage. Seeing the apple as red helps achieve this, though seeing the apple as some other color sufficiently different from the perceived color of the foliage would also suffice. On the other hand, the color visual system can only help the person manifest her ripe Red Delicious apple identification competence by outputting an experience sufficiently similar to the experiences *usually* elicited by ripe Red Delicious apples. An object re-identification competence "demands" that the perceived color of the apple doesn't vary too much with context, *i.e.,* that the apple doesn't look dramatically different in different lighting conditions or against different backgrounds. When I say that the demands of these competences converge, I simply mean that a (normal) color visual system *can* simultaneously help an organism manifest all these competences.

of the relevant competences line up; in the petal case the system cannot simultaneously enhance the manifestation of all the relevant competences but has to "choose" between them. This sort of conflict is a relatively rare occurrence, which explains the strangeness of the resulting experience.

5 Objections, replies, and further developments

I've proposed that we understand color vision as being competence-embedded and shown how the framework of competence-embeddedness can shed light on some puzzling color phenomena. In this section, I will consider some pertinent objections and suggest ways in which the view could be developed further.

5.1 Intuitions and common sense

It is common to criticize philosophical views of color and color perception for being counterintuitive or in conflict with common sense. Supposedly, when we experience colors, we experience them as being stable (perhaps even mind-independent) properties of objects. And, supposedly, the way we naturally think and talk about color suggests that there can be genuine disagreement about the colors of things. When a theory conflicts with these notions, it is often taken as evidence of the theory's falsehood. Tye's (2012) critique of Cohen's (2007, 2009) relationalism is a good example. Tye considers a hypothetical scenario where a perceiver observing a ball reports "That ball is yellow" and another perceiver observing the same ball reports "That ball is not yellow; it's pink." For Tye, the color attributions in this case are in direct competition. Intuitively, suggests Tye, there is genuine disagreement between the two perceivers, and at best only one of them can be right about the color of the ball. Because Cohen's relationalism entails that the ball instantiates both yellowness and pinkness in this scenario, and because this verdict is inconsistent with the alleged deliverances of intuition, Tye concludes that Cohen's view is wrong. Since CE also entails that both the yellow-involving experience and the pink-involving experience are simultaneously correct (or at least *can* be), the same objection applies.

There are at least two ways to respond to Tye. First, we can deny his claim about what is intuitively true about color and color perception. Second, we can resist the view that *commonsense* intuitions and *ordinary* discourse are what settle matters in philosophy of color. I shall focus on the first response here.

Here is my reading of Tye's hypothetical scenario: it is true that if I saw a ball as yellow and somebody else claimed to see it as pink, I might be somewhat worried. But, crucially, I wouldn't worry because I didn't find it metaphysically possible for the ball to simultaneously instantiate yellowness and pinkness. I would worry if I took my fellow perceiver to be a normal human color perceiver making a claim about the way the ball chromatically appears to normal human color perceivers in the conditions that we were both in at the time (this, I take it, is how we use color talk in most ordinary situations). Despite rampant interpersonal variation in color perception,[34] two normal perceivers of the same species do not usually see the same object as yellow and pink in the same conditions. So if my fellow observer saw the ball as pink, I might suspect that there was something abnormal going on with her perceptual processing; perhaps she was intoxicated or experiencing a migraine headache with visual aura. But if she then explained that she was, in fact, an atypical human color perceiver (with mutant cones or "an usual physiological condition" as Tye stipulates in his original example), or a normal *alien* color perceiver, my worry would dissipate.[35] In the language of CE, as long as she was manifesting some relevant competence (human or alien) by perceiving the ball as being pink, all would be fine and good.[36]

It is therefore not at all clear that intuitions are on Tye's side. This becomes even clearer when we consider the perception of fine-grained hues. Contrary to Tye, I have little trouble accepting that what is one shade of red to me might be a different shade of red to you, and that objects might simultaneously instantiate a variety of fine-grained hues.[37] Tye doesn't think that perceptual variation is a good enough to reason to let go of the notion of stable fine-grained object color. He denies that our inability to non-arbitrarily assign such colors to objects means that no such colors exist. This might be true, but Tye still needs to provide an argument for his claim that stable fine-grained colors do in fact exist. As far as I can see, his only reason for accepting this claim is common sense dogmatism. In his own words, "in the absence of a good reason to disbelieve the ordinary view, we are warranted in believing that view" (2012, 299). But Tye has neither shown that the view that he is putting forward as the commonsense view really *is* the commonsense view (and the only commonsense view), nor has he shown that the commonsense view should hold the kind of power that he claims it does (*i.e.,* that dogmatism is the way to go when it comes to color). In addition, there are, I believe, good reasons to disbelieve Tye's view. It entails rampant color misperception and renders color facts unknowable, among other things.

An attentive reader might now point out that the three desiderata sketched in §2 are also partially motivated by intuitions about color perception. Aren't the desiderata therefore just as suspect as the intuitions on

[34] See *e.g.* Shefrin and Werner 1990, Kuehni 2004.

[35] This way of thinking comes naturally to me. Empirical work by Cohen and Nichols (2010) suggest that it comes naturally to others as well.

[36] Note that CE also entails that many/most of the color experiences of atypical human color perceivers (*e.g.,* dichromats or anomalous trichromats) are correct.

[37] That said, I acknowledge that we can disagree about the referents of color terms. For example, if an object looks distinctly mint-green to me and a friend claims that it is turquoise, I might take her to be confused about the referents of 'mint-green' and 'turquoise,' on the assumption that the two of us live in fairly similar phenomenal worlds.

which Tye bases his criticism of Cohen? I think not. The intuitions I appeal to are philosophical intuitions that are much more robust than Tye's commonsense intuitions about the stability of true color. Though Tye's yellow/pink example might elicit in some people the kind of responses he is after, this is much less likely to happen if more intricate hypothetical scenarios are used. The three desiderata, on the other hand, are based on intuitions that are widely shared among philosophers who work on color and that do not rely on the use of specific thought experiments or scenarios.

5.2 The second desideratum and normal illusion talk

Another worry is that CE doesn't satisfy the second desideratum and cannot accommodate normal illusion talk. To elaborate on this worry, let us imagine a hallucinogen that interferes with the stages of cortical processing that correlate with conscious color experience, causing users to project seemingly random colors onto objects with which they perceptually interact. Let us dictate that all the contrast processing in the brain functions normally and the projecting of colors respects this processing in the sense that identical colors are never projected onto adjacent regions separated by a contour (this is a sense in which the projection is *not* random). If scenes are appropriately segmented and if the color visual system contributes to the segmentation, then it looks like at least one perceptual competence is manifested with the help of the color visual system. CE therefore entails that the distorted color experiences are correct. Yet, at the same time, this sounds like a fairly straightforward case of illusory color perception, since the experienced colors have little to do with the properties of the surfaces in question.

Could we rule this case out on the basis of the color experience being abnormally caused? This might seem plausible at first. The color visual system isn't functioning the way it normally functions; the hallucinogen interferes with the usual neural pathways and distorts the chromatic experience. So perhaps a way to defuse this objection is to simply require that color perception be competence-enhancing *in the normal way*. This requirement would also conveniently rule out experiences that occur due to some focal dysfunction in the brain, *e.g.,* a migraine with visual aura, a head trauma, or the influence of many (ordinary) hallucinogens. In all such cases the color experience is *potentially* useful, but only *accidentally* so. A translucent tomato-shaped red visual aura covering the part of a visual field where an actual tomato is located might accidentally help a perceiver identify a tomato as a tomato, but it is not the aim of the visual system to enhance this competence by producing the aura.

Notice, however, that in our imaginary hallucinogen case the color experiences are not accidentally useful. They are useful because the processing of chromatic edges plays a part in how the perceiver experiences the chromatic properties of her environment. Because the drug only interferes with the later stages of color perception and respects the competence-enhancing earlier processing, there is a sense in which the color visual system has *already fulfilled its function*. So perhaps the proponent of CE should just bite the bullet and accept that literally any color experience that directly and non-accidentally subserves the relevant competences is correct, even if there is something unusual about the experience itself.

Though I am sympathetic to this option, there is no denying that the colors experienced under the influence of the imaginary hallucinogen could be immensely confusing. A tomato might look chartreuse, trees purple, and the sky maroon. It might therefore seem counterintuitive to claim that such experiences are perfectly useful and correct. But note that an experience could be *minimally* useful/correct and confusing at the same time. To explain what I mean by this, I will now turn to the third objection.

5.3 When the chromatic experiences of normal perceivers dramatically diverge: "the dress" etc.

The last objection borrows its motivation from cases where the color experiences of normal human color perceivers radically diverge, and where the divergence isn't connected to differences in the absorption spectra of retinal cones, to normal neural adaptation, or to migraine headaches, hallucinogens, or any other unusual state of affairs. Perhaps the most striking example is the controversy surrounding "the dress," *i.e.,* the overexposed photograph of a dress that first became a viral internet sensation in 2015. The illumination cues in the image are ambiguous, and perceivers experience the colors of the dress in vastly different ways. Some see the dress as white and gold, others as black and blue, and a small minority as some other combination of colors.[38]

"The dress" poses a problem for CE because CE appears to entail that the perceivers in the different camps all experience the colors in the image correctly, as long as those experiences are tied to the manifestation of some relevant competence. But this sounds rather strange, especially if we think that this sort of divergence could potentially extend to situations where observers are viewing actual objects (and not just photographs of objects) in some atypical viewing conditions. To see why, imagine that two subjects are viewing the actual dress through an aperture in a laboratory where vision scientists have carefully created ambiguous lighting cues comparable to those in the original photograph (the practical possibility of this need not concern us here). Now imagine that Subject A sees the dress as black and blue and Subject B sees it as white and gold, but when they are shown the same dress in normal daylight conditions, they both see it as black and blue.

[38] The differences might reflect certain "internal priors" of the perceivers: the perceivers in the different camps might "favor" and expect different kinds of illuminants (see Lafer-Sousa et al. 2015).

The question is: is it reasonable to insist that the subjects' divergent color-involving experiences in the aperture viewing condition are both correct?

There are at least two plausible ways the proponent of CE could respond. First, she could argue that the two experiences are equally correct and that the controversy concerning the color of dress is purely doxastic.[39] In short, Subject B's experience of the dress as white and gold is not itself mistaken but if she then forms the belief, on the basis of that experience, that the dress looks white and gold to her (and to perceivers like her) in most ordinary perceptual circumstances, she is clearly wrong. And so the *belief* is erroneous, not the experience itself. That said, it is unclear whether this strategy can appease intuitions about the two experiences themselves being on an unequal footing. Many would likely argue that there is still something askew about Subject B's white-and-gold experience even in the absence of any subsequent beliefs about the way the dress normally appears.

Luckily, CE also admits of a more complex response. Note that the experience of the dress as black and blue in the aperture viewing condition might help Subject A manifest an additional competence: *object re-identification*. Because her chromatic experience remains relatively stable across the two conditions, it is easier for her to recognize the dress as being the same dress (or at least a dress with similar material properties). And if her experience helps her manifest *more* competences, then perhaps her experience is also *more* correct than Subject B's experience in the aperture condition.

Though this might sound a bit odd initially, recall that CE analyzes correctness in terms of usefulness. Since usefulness admits of degrees (both a key and a hammer can be useful for getting through a locked door, but the right kind of key is usually more useful than a hammer), then arguably correctness-as-usefulness can too. It is useful (competence-enhancing) to perceive the dress as white and gold, but even more useful (competence-enhancing) to perceive it as black and blue. And so we could say that *it is also more correct to perceive the dress as black and blue*.[40]

Going back to the earlier example, we could now say that an experience of a visual scene under the influence of the imaginary hallucinogen is minimally correct, but less correct than an experience of the same scene when the color system is functioning normally. This would allow us to analyze the apparent illusoriness of some perceptual cases as having to do with a lesser degree of correctness than we might normally expect, and the disagreement between some perceptual variants as a disagreement about

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[39] This option is inspired by Cohen 2009.

[40] "Non-pragmatist" views seem antithetical to this line of reasoning. For example, if color is equated with some microphysical property and veridical color perception is understood in terms of accurate detection of this property, then there exists a rigid binary of correct and incorrect color perception. CE is consistent with both the rigid boundary option and the gradated option, and those who find the idea of degrees of correctness unsavory can still accept the core tenets of CE.

which variant is *more* correct. Notice, however, that this sort of analysis doesn't apply to cases like the pink/grey petals where the demands of the relevant competences themselves are in conflict. The structural dissimilarity between the hallucinogen case and the pink/grey petals case is reflected in the structural dissimilarity of the respective explanations.

6 Conclusion: the three desiderata revisited

CE appears to largely avoid the pitfalls that plague many other philosophical views of color perception. First, it doesn't entail widespread color visual system failure: insofar as most of our color experiences result from processing that directly and non-accidentally subserves the manifestation of relevant competences, the view entails that color visual systems usually function the way they are supposed to function (*desideratum 1*). At the same time, CE does allow for instances of unsuccessful color perception: if a particular color experience results from processing that doesn't directly and non-accidentally contribute to the manifestation of any relevant competences, it is incorrect (*desideratum 2).* Finally, CE allows us to unambiguously differentiate between instances of correct color perception and instances of incorrect color perception, and to use these standards to evaluate and explain a wide variety of color perceptual phenomena (*desideratum 3*). A great deal of explanatory power comes from the distinction between ideal and non-ideal good cases of color perception. Many textbook color illusions count as non-ideal good cases, and CE allows us to explain their apparent strangeness without attributing failure to the system itself. In addition, because CE allows for degrees of correctness, it allows us to maintain that some color experiences are more correct than others, even if all the candidate experiences result from competence-enhancing processing.

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