Quality-Space Functionalism about Color*

Forthcoming in *The Journal of Philosophy*

(Please quote the published version.)

Roses are red, or so you might think. But what is it for an object to be red—or any other color for that matter? I motivate and defend here a previously underdeveloped theory of the metaphysics of color that I call 'quality-space functionalism' ("QSF") about color.[1]

Theories of color in the current literature typically come in three varieties: *anti-realist* views such as projectivism and eliminativism, which deny that external objects are colored, and two kinds of *color realism*: *mind-dependent* views such as dispositionalism and relationalism, which characterize the colors of objects in terms of their effects on or their relations to perceivers, and *mind-independent* views such as physicalism and primitivism, which take objects to be colored whether or not individuals may be present to see them.[2]

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* Many thanks to Nobel Ang, Ralph Baergen, Joshua Gert, Laura Gow, William McCurdy, Myrto Mylopoulos, Bence Nanay, James Norris, Melissa Norton, David Pereplyotchik, Evan Rodriguez, David Rosenthal, Peter Ross, James Skidmore, Russell Wahl, John Whelan, Douglas Young, the audience at the Fall 2019 Philosophy Colloquium at Carleton University, members of the Spring 2020 Neuroscience Colloquium at Lycoming College, and two referees for this journal for their helpful comments on drafts or discussions of this material.

[1] QSF has roots in the work of many theorists including, for example, Willard Van Orman Quine, *Word and Object* (Cambridge, MA: MIT Press, 1960); Wilfrid Sellars, *Science, Perception and Reality* (London: Routledge and Kegan Paul, 1963); David Lewis, "Psychophysical and Theoretical Identifications," *Australasian Journal of Philosophy*, L, 3 (December 1972): 249–58; and Sydney Shoemaker, "The Inverted Spectrum," this JOURNAL, LXXIX, 7 (July 1982): 357–81. The view is more recently suggested in some form or another in the work of David Rosenthal and Austen Clark. See, for example, David M. Rosenthal, "The Independence of Consciousness and Sensory Quality," *Philosophical Issues*, I (1991): 15–36; Rosenthal, "Color, Mental Location, and the Visual Field," *Consciousness and Cognition*, X, 1 (March 2001): 85–93; David M. Rosenthal, *Consciousness and Mind* (Oxford: Clarendon Press, 2005); David Rosenthal, "How to Think about Mental Qualities," *Philosophical Issues*, XX, 1 (October 2010): 368–93; David M. Rosenthal, "Quality Spaces and Sensory Modalities," in Paul Coates and Sam Coleman, eds., *Phenomenal Qualities: Sense, Perception, and Consciousness* (Oxford: Oxford University Press, 2015), pp. 33–65; Austen Clark, *Sensory Qualities* (Oxford: Clarendon Press, 1993); and Austen Clark, *A Theory of Sentience* (Oxford: Clarendon Press, 2001). QSF is also alluded to in some degree in Jacob Berger, "A Defense of Holistic Representationalism," *Mind and Language*, XXXIII, 2 (April 2018): 161–76. But most of these accounts focus on the nature of *color vision*—that is, the nature of the mental qualities or representations that figure in the visual perception of color—rather than the nature of the colors themselves. The view thus deserves explicit treatment and further development.

[2] For examples of projectivism and eliminativism, see, respectively, Paul A. Boghossian and J. David Velleman, "Colour as a Secondary Quality," *Mind*, XCVIII, 398 (January 1989): 81–103; C. L. Hardin, *Color for Philosophers: Unweaving the Rainbow*, expanded edition (Indianapolis: Hackett, 1993). For examples of dispositionalism and relationalism, see, respectively, Janet Levin, "Dispositional Theories of Color and the Claims of Common Sense," *Philosophical Studies*, C, 2 (August 2000): 151–74; and Jonathan Cohen, *The Red and the Real: An Essay on Color Ontology* (Oxford: Oxford University Press, 2009). For examples of physicalism and primitivism, see, respectively, Alex Byrne and David R. Hilbert, "Color Realism and Color Science," *Behavioral and Brain Sciences*, XXVI, 1 (February 2003): 3–21; and Joshua Gert, *Primitive Colors: A Case Study in Neo-pragmatist Metaphysics and Philosophy of Perception* (Oxford: Oxford University Press, 2017). For an overview of such theories, see, for example, Laura Gow, "Colour," *Philosophy Compass*, IX, 11 (November 2014): 803–13. The distinction between mind-independent and mind-dependent views of color roughly tracks the so-called "primary-secondary quality" distinction in the history of philosophy; for discussion, see, for example, Boghossian and Velleman, "Color as a Secondary Quality," *op. cit.*; and Alex Byrne and David R. Hilbert, "Are Colors Secondary Qualities?," in Lawrence Nolan, ed., *Primary and Secondary Qualities: The Historical and Ongoing Debate* (Oxford: Oxford University Press, 2011), pp. 339–61.

Various theorists have offered an array of desiderata for such theories.[3] At bottom, theories of color seek to reconcile our ordinary conception of color,[4] facts about the phenomenology of color experience, and experimental findings about the visible surfaces of objects and color vision. In addition, theories of color often hope to balance more general metaphysical considerations, such as a commitment to *naturalism*—the attractive view that all objects and properties, including colors, are scientifically tractable phenomena explainable in physical terms. Setting aside anti-realist views, which are not genuinely theories of objects' colors so much as explanations of our purportedly mistaken impression that external things are colored, varieties of mind-dependent and mind-independent theories have their advantages.

Consider, for example, standard versions of color physicalism, which identify the colors with (sets of) physical properties of objects such as surface spectral reflectances ("SSRs"). Since such mind-independent theories are straightforwardly naturalistic, one might think that they would fit best with the science of color. But such views often struggle to explain certain experimental findings about color perception, such as the well-known evidence of apparently widespread *perceptual variation*, wherein the same object looks to be different colors to varied creatures under the same conditions or looks to be different colors under varied conditions to the same creature.[5] Color physicalism seems ill suited to explain such variation in part because it appears arbitrary to maintain that some but not other individuals accurately see the colors. Considerations of perceptual variation are thus often cited as the prime motivation for mind-dependent theories such as color relationalism,[6] which take colors to be relations between perceivers and perceived objects. But the latter sorts of views face other problems. Common sense, for example, would seem to hold that the colors are "out there" and thereby capable of being misperceived, but varieties of color relationalism arguably do not permit the possibility of color misperception. One might conclude that our only recourse is to endorse a version of color primitivism,[7] which takes the colors to be irreducible *sui generis* features of objects. But such views eschew naturalism altogether.

QSF aims to strike a middle ground between these various approaches. QSF is realist theory of color compatible with naturalism. In short, it identifies and individuates the colors by their relative locations within a particular kind of so-called 'quality space' that reflects creatures' capacities to discriminate visually among stimuli. In other words, colors are theorized to be categorical features of objects functionally characterized in terms of their causal relations to creatures' visual discriminatory behaviors, as captured by the relevant quality space.[8]

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[3] See, for example, Gow, "Colour," *op. cit.*, pp. 803–04; and Gert, *Primitive Colors*, *op. cit.*, pp. 88–89.

[4] Why care about our ordinary conception of color? As Wilfrid Sellars famously urged in *Science, Perception and Reality*, *op. cit.*, chapter 1, when trying to explain ordinary features of the world in ways that are consonant with our scientific findings, we must begin with our commonsense understandings of things in order to theorize about their underlying natures. Once we have those understandings, we may theorize about phenomena in ways that may alter those understandings. But we should remain careful not to depart from common sense too much, lest it become unclear that we develop theories of the relevant phenomena.

[5] For discussion, see, for example, Gow, "Colour," *op. cit.*, pp. 805–07.

[6] See, for example, Cohen, *The Red and the Real*, *op. cit.*, p. 24ff.

[7] See, for example, Gert, *Primitive Colors*, *op. cit.*, p. 87ff.

[8] Proponents of precursors of this view often maintain that it applies to the perceptible or sensible properties accessed by all modalities, such as sounds, shapes, and even pains. See, for example, Rosenthal, "How to Think about Mental Qualities," *op. cit.*, pp. 377–78. But some theorists have argued that a uniform treatment of perceptible properties is incorrect. On how odors and color may differ, for example, see Clare Batty, "What's That Smell?," *The Southern Journal of Philosophy*, XLVII, 4 (Winter 2009): 321–48. I thus focus here only on the case of color, as it would seem to be the most natural candidate for this quality-space-theoretic treatment. But to understand how the view may extend to the olfactory perception of odors, see Benjamin Young, Andreas Keller, and David Rosenthal, "Quality-Space Theory in Olfaction," *Frontiers in Psychology*, V (January 16, 2014): 1–15.

I begin in section I by laying out a rationale for QSF and providing basic details about the view. Then, in section II, I highlight how QSF meets several of the theoretical desiderata on a theory of color as well as some of its advantages over standard accounts. My arguments for QSF here are abductive: I propose that QSF fits well with both our folk conception of color and the phenomenology of color experience, as well as accommodates many relevant experimental findings. Section III focuses on the phenomenon of perceptual variation in particular, arguing that QSF explains it in a satisfying manner. Throughout, I urge that QSF avoids many criticisms of alternative theories. Since Jonathan Cohen too presents his brand of color relationalism as a kind of functionalism about color—and because QSF has much in common with it—it is often helpful to use this theory as a main point of comparison.[9] I close, for example, by showing how QSF avoids color relationalism's troubles with explaining color misperception in section III.3.

I. Quality-Space (Color) Functionalism

Quality spaces in general are systems of organizing perceptible stimuli along various dimensions.[10] Since quality spaces of colors impose orderings on the colors, they would seem to be a natural place to look to develop a theory that identifies and individuates the colors. A serious problem, however, is that there are many such spaces—the Swedish Natural Color System and the Munsell Color System to name just two—which are developed in different ways for different theoretical purposes. One might thus worry that there are no principled grounds to select one quality space as truly characterizing the colors.

I argue that there are good reasons to understand the colors in terms of the quality space that reflects creatures' capacities to visually discriminate stimuli in respect of their colors—what I call the 'standard color discriminatory space'. One of the main reasons to accept this view is that it fits well with a theory of perceptual content, versions of which have been developed and defended perhaps most notably by David Rosenthal and Austen Clark.[11] Because such a theory of perceptual

[9] See Cohen, *The Red and the Real, op. cit.* Others have also recently defended views in the vicinity of QSF. Peter Ross sketches a kindred account based on quality spaces, but he develops it as a kind of color physicalism. See Peter W. Ross, "Fitting Color into the Physical World," *Philosophical Psychology*, XXIII, 5 (2010): 575–99. Similarly, Alistair Isaac and John Morrison defend views that they call respectively 'structural realism' and 'structuralism', which have something in common with QSF. See Alistair M. C. Isaac, "Structural Realism for Secondary Qualities," *Erkenntnis*, LXXIX, 3 (June 2014): 481–510; John Morrison, "Anti-Atomism about Color Representation," *Noûs*, XLIX, 1 (March 2015): 94–122; and John Morrison, "Perceptual Variation and Structuralism," *Noûs*, LIV, 2 (June 2020): 290–326. On Isaac's view, visual experiences may be veridical even though colors do not exist because color experiences fall into structures that correspond to spaces of objects' physical lightness-reflectance profiles. Morrison likewise holds that perceptual experiences' contents are determined by their occurrent comparisons of relations between perceived properties. But, again, QSF is a theory of color, not visual representation. Moreover, as we shall see in section I, the theory of perceptual content with which QSF most naturally fits differs from these views insofar as it does not involve representation of occurrent comparisons between properties, which arguably does not fit with color phenomenology, nor does it deny the reality of colors, which undermines common sense.

[10] For overviews of various color systems, see, for example, Rolf G. Kuehni, "Color Spaces and Color Order Systems: A Primer," in Jonathan Cohen and Mohan Matthen, eds., *Color Ontology and Color Science* (Cambridge, MA: MIT Press, 2010), pp. 3–36; and Diana Raffman, "Similarity Spaces," in Mohan Matthen, ed., *The Oxford Handbook of Philosophy of Perception* (Oxford: Oxford University Press, 2015), pp. 679–93.

[11] See, for example, Rosenthal, "The Independence of Consciousness and Sensory Quality," *op. cit.*; Rosenthal, *Consciousness and Mind*, *op. cit.*; Clark, *Sensory Qualities*, *op. cit.*; and Clark, *A Theory of Sentience*, *op. cit.* Versions of this view differ in their details; Rosenthal maintains, for example, that such a view explains the character of spatial perception, which Clark denies. But for the purposes of presenting the view and developing QSF, such differences do not matter.

representation is based on the discriminatory space, I have elsewhere called this kind of view 'quality-space semantics' ("QSS").[12]

I.1. Quality-Space Semantics. QSS is motivated by the folk-psychological idea that each of our sensory systems gives us perceptual access to discrete *families* of perceptible properties. Olfaction gives us perceptual access to the odors and audition to the sounds. In the case of color, it is plain that vision enables us to draw distinctions among stimuli in respect of their colors. And as is well known, what colors creatures are able to discriminate visually under standard viewing conditions (more on such conditions shortly) can be experimentally charted into a particular kind of quality space, which is a map of the similarity-and-difference relations among those stimuli as they are discriminated by sight.[13] Since vision discriminates red stimuli as being more similar to orange stimuli than to green stimuli, red stimuli are located more closely to the orange stimuli than they are to the green stimuli in the quality space.

Although perceptual psychologists construct this quality space on the basis of actual discriminations among particular colored stimuli such as Munsell color chips, the space is a map of creatures' *dispositions* to engage in visual discriminatory behaviors—that is, of how creatures *would* visually discriminate *any* stimuli in respect of their colors. We can thus regard each location in the space as the equivalence class of all stimuli that have the same discriminability profile. And since objects' colors are the properties in virtue of which creatures make or would make the relevant discriminations, each equivalence class is identical with, or at least corresponds to, each color property as it is (or would be) discriminated.[14] The total set of color properties, then, constitutes a multidimensional space, typically thought to be ordered along the dimensions of hue, saturation, and brightness. This is the standard color discriminatory space.

QSS maintains that the best explanation of creatures' distinctive abilities to discriminate among colors in the ways captured by this space is that they are able to form visual representations that vary among one another at least as finely as the colors to which they provide access. We as perceptual psychologists thus posit a space of visual representations of color that are simply extrapolated from, and thereby correspond to, the matching color discriminatory space. The color discriminatory space thereby imposes an ordering on the colors that is mirrored in the ordering of the color-visual states in the matching space of color-visual representations. Just as we observe that there is the color discriminatory space in which red is located more closely to orange than it is to green, for example, we posit a space of color-visual states in which the visual representation of red is located more closely to the visual representation of orange than it is to the visual representation of green.

Though such a space of visual states is a model or representation of creatures' capacities to discriminate among colors—like its corresponding color discriminatory space, the space is not itself represented in the mind—it can be used to identify and individuate creatures' visual contents. This is because such a map must be *asymmetrical*. If there were an axis of symmetry, indiscriminable colors could be placed on either side of the axis. But since the discriminatory space is generated via creatures' discriminatory behaviors, any such placements would be redundant—and so such a

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[12] Berger, "A Defense of Holistic Representationalism," *op. cit.*, p. 166.

[13] On such a space, see, for example, Quine, *Word and Object*, *op. cit.*, p. 83ff; and Shoemaker, "The Inverted Spectrum," *op. cit.*, p. 361ff.

[14] I do not take a stand here on the metaphysics of properties—that is, whether or not properties are abstract universals, nominalistically identifiable with sets of objects, tropes, or some other view. For an overview of theories of properties, see, for example, the essays in D. H. Mellor and Alex Oliver, eds., *Properties* (Oxford: Oxford University Press, 1997). In what follows, I write interchangeably as though it is colored stimuli or the color properties themselves that can be discriminated and that thereby vary in the color space.

situation is by hypothesis impossible.[15] And we find this result experimentally: the color discriminatory space does exhibit such asymmetries. Human adults with normal color vision, for example, can discriminate more shades of bright saturated yellow than of bright saturated blue. Each color-visual state thus occupies a *unique* location within the color-visual space, which may identify and individuate it via its location within the color-visual space alone. According to QSS, for example, a visual representation of red represents the color red because that visual state occupies a location within the space of visual representations of color that matches the location of red within the quality space of colors.

QSS is unlike most standard theories of perceptual content, which are typically atomistic insofar as they hold that a creature's visual perception of a particular color does not depend in any way on its capacity to see other colors. On Michael Tye's well-known view, for example, a perceptual state *S* represents that there is some perceptible property *P* present just in case if, in optimal conditions, *S* would be tokened if and only if and because *P*.[16] QSS, by contrast, is *quasi-holistic* insofar as color-visual contents are identified and individuated by relations to a restricted class of other perceptual states—namely, those within the color-visual space. On this view, a creature cannot see any color unless it is able to see a sufficient number of other colors.[17]

I.2. QSF Introduced. Since it is reasonable to hold that we typically see the colors of objects accurately, it would seem that QSF is tailor-made for QSS.[18] That is to say, considerations of QSS should lead us to accept:

> *Quality-Space Functionalism* ("QSF") about color: Each color is identified and individuated by its unique relative location within the standard color discriminatory space.

Accordingly, QSF collapses the distinction between a color as it is discriminated and that color itself. For an item to exhibit a particular color—for example, for a stimulus to be a particular shade of red—is simply for it to be typically discriminated in a particular way: as occupying a particular location, relative to all other locations, within the color discriminatory space. Again, because the color discriminatory space is asymmetrical, each location within the space is unique, thereby identifying and individuating each color by its location within the color space alone. QSF is thus, like QSS, a quasi-holistic theory: the nature of a particular color invariably references all of the other colors that creatures are disposed to discriminate from it.

Crucially, I maintain that it is the color discriminatory space—the space that perceptual psychologists construct to reflect facts about certain of our visual discriminatory capacities—that best captures our commonsense conception of color. Folk psychology would seem to hold that the colors are simply the actually existing properties of mind-independent objects that we see as having particular visually available similarity-and-difference relations to one another. We both see and think about red just as that feature of objects that we discriminate as more similar to orange than to green,

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[15] See, for example, Rosenthal, "How to Think about Mental Qualities," *op. cit.*, p. 380.

[16] See Michael Tye, *Consciousness, Color, and Content* (Cambridge, MA: MIT Press, 2000), p. 136.

[17] This overview of QSS should suffice for present purposes. For some *prima facie* objections to the view, see, for example, Jesse J. Prinz, *The Conscious Brain: How Attention Engenders Experience* (Oxford: Oxford University Press, 2012), p. 132; Joshua Gert, "Quality Spaces: Mental and Physical," *Philosophical Psychology*, XXX, 5 (2017): 525–24. For additional defenses of QSS, see, for example, Rosenthal, "How to Think about Mental Qualities," *op. cit.*; and Berger, "A Defense of Holistic Representationalism," *op. cit.*

[18] The combination of these views is not, however, necessary. One might, for example, endorse QSF while maintaining some version of an atomistic theory of perceptual content of the sort defended by Tye. Alternatively, one could accept a version of QSS but endorse, for instance, a version of color primitivism. But, as we shall see, adopting both QSF and QSS does create an attractive package regarding not only the colors but also our visual representation of them.

and so forth. Rival theories of color typically explain the colors in terms of factors other than how they are discriminated from one another—such as how colored surfaces reflect light or light information is processed in the visual system. But while such factors are plainly relevant to our understanding of color, QSF maintains that they do not explain what, fundamentally, colors are.

For these reasons, the relevant color space is not likely to be equivalent to the kinds of spaces that vision scientists or metaphysicians of color typically construct, which are often generated on the basis of considerations other than how the colors are discriminated. The Swedish Natural Color System, for example, is based upon the *opponent-processing model* of color vision; it is generated by taking as basic the six purportedly opponent elementary colors and inviting perceivers to make judgments about the relative percentages of blackness and two of the elementary colors of color stimuli.[19] As a result, this space differs from the relevant space in important ways; unlike the color discriminatory space, for example, the Swedish Natural Color System is symmetrical—and so could not provide a clear means for identifying and individuating the colors via their locations in the space alone.

This characterization of QSF, however, may seem circular insofar as it delineates the colors in terms of their locations within the *color* discriminatory space—and thus may seem to require an independent understanding of the colors to construct the relevant space in the first place. But QSF assumes that the discriminatory space can be described in purely nonmental and noncolor terms. To pick out the relevant features of stimuli—or, to adapt an expression of Saul Kripke's, *to fix the reference* of our investigations[20]—we use aspects of our commonsense conception of colors, which regards them as, for example, those properties of objects that we can see, that appear to co-vary with lighting conditions, that establish the boundaries of the shapes that we see, and so forth. Perceptual psychologists map how creatures discriminate stimuli in respect of those features, whatever these features may be.

Moreover, QSF assumes a purely *behavioral* notion of discrimination, which can be suitably operationalized, experimentally measured, and characterized in nonmental terms. Many procedures would seem to be suitable candidates for constructing the relevant space.[21] We might, for example, use a method in which we present individuals with successive pairs of stimuli such as Munsell color chips to determine whether there are so-called 'just noticeable differences' ("JNDs") between the stimuli—that is, pairs of stimuli that are so physically similar that if they were any more physically similar they would be indistinguishable—or examine simply whether or not creatures are able to match the stimuli.[22] From the perspective of QSF, however, it remains an open experimental question how best to measure and chart creatures' visual discriminatory capacities.[23]

The manner in which the color discriminatory space is constructed will determine not only the metric for measuring the distance between colors, but also the dimensions of the color space

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[19] See, for example, Kuehni, "Color Spaces and Color Order Systems," *op. cit.*, p. 27.

[20] Saul Kripke, *Naming and Necessity* (Cambridge, MA: Harvard University Press, 1980), p. 55.

[21] See, for example, Nelson Goodman, *The Structure of Appearance* (Cambridge, MA: Harvard University Press, 1951), pp. 222–26; Clark, *Sensory Qualities*, *op. cit.*, chapter 3; Rosenthal, *Consciousness and Mind*, *op. cit.*, pp. 201–02; and Rosenthal, "How to Think about Mental Qualities," *op. cit.*, p. 390, fn. 23.

[22] For the benefits of a JND method, see, for example, Rosenthal, "Quality Spaces and Sensory Modalities," *op. cit.*, p. 37ff.

[23] One might instead think that the space relevant for identifying the colors is generated in terms of *perceived* similarities and differences between stimuli, but there are several reasons to prefer the discriminatory space as the relevant space. For one thing, the discriminatory space plainly fits with QSS, whereas a latter sort of space requires an independent characterization of perceived similarities and differences. Moreover, the discriminatory space is arguably finer grained and less subjective than a space based on perceived relations. See, for example, Rosenthal, "Quality Spaces and Sensory Modalities," *op. cit.*, pp. 35ff. I thank an anonymous referee for this journal for emphasizing to me the importance of this distinction between kinds of spaces.

itself—that is, the ways in which colors may differ from one another. If, for example, a JND-based method proves to be the correct method for capturing the color discriminatory space, then the metric for measuring the distance between colors would be number of JNDs. It might be, for example, that the fact that a certain shade of red is more similar to a certain shade of orange than to a shade of green is reflected in the discriminatory space insofar as the red is fewer JNDs to the orange than to the green. But QSF is compatible with alternative metrics of relative distance in the space. Likewise, the relevant dimensions of the color space emerge depending on the method in which we construct the space.[24] Though the colors are typically thought to be ordered along the three dimensions of hue, saturation, and brightness, the selection of the relevant dimensions for characterizing the color discriminatory space need not be straightforward.[25] And QSF is compatible with the colors' being ordered in alternative ways.

How does QSF account for the difference between determinate colors such as red$_{23}$ or determinable colors such as red? Determinate colors are explained straightforwardly: there are as many determinate colors as there are locations within the discriminatory space. Red$_{23}$ occupies a particular node within the space. But the view has the resources to explain determinable colors as well. Like standard versions of color physicalism, QSF regards colors as *types*[26]—that is, as (corresponding to) sets of properties of stimuli grouped as they are discriminated. According to QSF, determinable colors such as red are simply regions or sets of relevant nodes, such as the region comprising all of the determinate red nodes. Of course, the boundaries between determinable colors may be vague; there may seem to be no principled reason to regard particular determinate colors as belonging to certain regions and hence as being certain determinable colors (it may, for example, be unclear whether a particular node is a reddish orange or an orangish red). But if anything, that result is to be expected.[27]

It may, however, seem that there are experimental obstacles to determining the relevant space. For example, while identity is plainly transitive—if *A* is identical with *B* and *B* is identical with *C*, then *A* is identical with *C*—it is well known that color discriminability seems to be *intransitive*.[28] There would seem to be examples of color stimuli for which, when viewed simultaneously as pairs, color chips *X* and *Y* are indiscriminable and color chips *Y* and *Z* are indiscriminable, but color chips *X* and *Z* are discriminable. And such facts may make it seem as though we cannot construct a color discriminatory space, which entails we cannot thereby identify and individuate the colors in this way.

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[24] See, for example, Clark, *Sensory Qualities*, *op. cit.*, chapter 4.

[25] See, for example, Alex Byrne, "Inverted Qualia," in Edward Zalta, ed., *The Stanford Encyclopedia of Philosophy* (Winter 2018 Edition), URL = <https://plato.stanford.edu/archives/win2018/entries/qualia-inverted/>, section 2.2., fn. 13.

[26] See, for example, Byrne and Hilbert, "Color Realism and Color Science," *op. cit.*, p. 10.

[27] Since it would seem that we often see objects' colors in indeterminate ways—we might visually experience an apple as red, but not as any particular shade of red—one might nonetheless wonder how the combination of QSS and QSF can explain indeterminate color perception. But there are two things to note. First, since my primary goal here is to defend QSF, and since the combination of QSS and QSF is optional, QSF need not explain anything about color perception. But QSS arguably does have resources to explain indeterminate color experience. According to QSS, each individual at a time exhibits a particular color-visual space (for more, see section III.2), which reflects its capacity to discriminate among colored stimuli at that time. And since at any given moment a creature may not be able to distinguish each determinate color as characterized by its location in the standard color space, each location within a creature's *individual* space of color-visual states may correspond to a range of colors. In other words, there may be a one-to-many, or *homomorphic*, mapping of locations within one's color-visual space to locations within the standard color space. See, for example, Rosenthal, *Consciousness and Mind*, *op. cit.*, p. 198ff. Indeterminate color perception thus may occur when creatures are in visual states that do not distinguish and thereby represent stimuli as occupying any location within a region or subset of the color space. But this is just one explanation of some instances of indeterminate color perception—and proponents of versions of QSS or other theories of perceptual content may offer other or additional ways of accounting for it. See, for example, Rosenthal, *Consciousness and Mind*, *op. cit.*, p. 186ff.

[28] See, for example, Goodman, *The Structure of Appearance*, *op. cit.*, p. 220.

I have more to say about how the color discriminatory space can and should be constructed in section III. But for now, I note that there would seem to be sophisticated experimental techniques available. Rosenthal, for example, urges that we can construct the relevant discriminatory space by merging both a JND and matching method; he writes:

> The methodology of JNDs delivers results that are not transitive; one stimulus can be JND from a second and the second from a third without the first being JND from the third. An alternative methodology is that of matching: Instead of making stimuli physically closer until they're perceptually indistinguishable, start with physically identical stimuli and make them physically diverge until they become perceptually distinguishable. Matching also delivers results that are not transitive; a can match b and b match c without a's matching c. But as Nelson Goodman (1951: 221) in effect notes, matching allows for a neater individuation of types than JNDs; we can rule that one stimulus is perceptually the same as another if, but only if, they perceptually match all the same stimuli. And that allows us in turn to handle the failure of transitivity of being JND; two stimuli are JND as soon as matching fails.[29]

To adapt some terminology from Clark,[30] the relevant notion of behavioral discriminability for constructing a space of discriminatory abilities is not mere indiscriminability in terms of sameness of perceptual effect under some conditions or other—what we might 'local' indiscriminability—but something akin to what he calls 'global' indiscriminability. Two stimuli are globally indiscriminable if the best methods for assessing discriminability—for example, a combined JND and matching method—do not distinguish them (for example, there is no stimulus that is discriminable from only one member of the pair under standard viewing conditions). In the example above, although the pairs of chips *X*, *Y*, and *Z* are locally indiscriminable under some conditions, they are nonetheless all globally discriminable from one another. While local indiscriminability is not transitive, global indiscriminability is.[31] The color discriminatory space must therefore somehow reflect global discriminability.[32]

Determining the technique for assessing (global) discriminability ultimately amounts to *epistemic* or experimental difficulties that must be addressed in the course of constructing the color discriminatory space.[33] Once again, the color discriminatory space represents creatures' dispositions to engage in color discriminatory behavior. And it may be hard to *know* or experimentally measure what these dispositions may be. But, at any given time, there is a fact of the matter about what creatures' discriminatory dispositions are that can be, at least in principle, charted into a color discriminatory space. The issue of how best to construct such a space thus remains an open experimental issue largely to be left to perceptual psychology.

I.3. QSF and Functionalism. Why does QSF amount to a kind of functionalism about color properties? QSF characterizes colors by their roles in causing discriminatory behavior, as captured by the discriminatory space. The view thus understands colors much in the same way that ordinary folk-psychological functionalism about mentality characterizes mental states.[34] Folk-psychological functionalism holds that mental states can be explained not (solely) by what they are made of but, roughly, by the roles that they play in causing other mental states and behavior.

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[29] Rosenthal, "Quality Spaces and Sensory Modalities," *op. cit.*, p. 38, fn. 3.

[30] Clark, *Sensory Qualities*, *op. cit.*, chapter 2, especially pp. 58–59.

[31] For an alternative defense of the idea that perceptual indiscriminability is transitive, see, for example, Delia Graff, "Phenomenal Continua and the Sorites," *Mind*, CX, 440 (October 2001): 905–35.

[32] All references to discriminability going forward refer to this kind of global discriminability, unless otherwise noted.

[33] See also, for instance, Young, Keller, and Rosenthal, "Quality-Space Theory in Olfaction," *op. cit.*, p. 2.

[34] See, for example, Lewis, "Psychophysical and Theoretical Identifications," *op. cit.*

Functionalist theories come in roughly two varieties: so-called 'role' and 'realizer' functionalisms.[35] In short, role-functionalist theories identify their explanatory targets with the relevant causal roles, whereas realizer-functionalist views identify their *explananda* with the realizers of those roles. A role functionalist account of beliefs, for example, holds that beliefs are whatever play the "belief role," where such a role is described in terms of belief states' causal relations to other mental states and behavior. In that way, role-functionalist theories are accounts of higher-order properties—the properties of properties' playing such-and-such roles. On a realizer-functionalism about beliefs, by contrast, beliefs are identical with whatever realizes the belief role; in human beings, these are presumably certain kinds of neural states. Such realizers can be identified using the standard *Ramsey-Lewis method*,[36] wherein we collect descriptions of the relevant causal roles and replace the terms for the *explananda* with bound variables. The resultant *Ramsey sentence* then functions as a characterization of the target in terms of their causal roles—and the values of the bound variables are the realizers that fulfill those roles, whatever they may be.

QSF is role functionalist. Since QSF characterizes colors in terms of their roles in eliciting discriminatory behavior, the view does not require that the realizers of those roles vary in any straightforward way in terms of how they may be physically characterized. It need not even be the case that such realizers are physical. According to QSF, colors are multiply realizable by whatever properties of stimuli are those in virtue of which the stimuli have their discriminability profiles—that is, in virtue of which they belong in the relevant equivalence classes. We may of course identify the realizers of such roles, whatever they may be—for example, SSRs, nonphysical features of objects, and so on—using the Ramsey-Lewis method, just as standard role functionalism about mental states is compatible with the realizers of role functionally characterized mental states' being (potentially quite disparate) physical features of creatures that can be described in nonmental vocabulary such as brain states. And since theories that are naturalistic are to be preferred if workable, the realizers of colors will likely be sets of SSRs. But according to QSF, colors are, metaphysically speaking, not identical with sets of SSRs, as standard versions of color physicalism hold, but role functionally characterized in terms of their locations in the color space.[37] So while QSF is not a *reductive* theory such as color physicalism, it is plausibly naturalistic.

Again, QSF is not the only functionalist theory of color currently available; Cohen, for example, regards his version of color relationalism as role functionalist.[38] Although common sense, QSF, and many other standard theories of color such as versions of physicalism take colors to be monadic features of objects, Cohen's view holds that colors are relational properties of the form *being color X for perceiver S under viewing conditions C*. And Cohen characterizes his functionalist relationalism in this way: "*red for* S *in* C is the functional role of disposing its bearers to look red to S in C, and *green for* S *in* C is the functional role of disposing its bearers to look green to S in C. *Mutatis mutandis* for the other colors."[39]

QSF and Cohen's functionalism thus share in common that colors are characterized by their causal roles, not by whatever may realize those roles. But on Cohen's view, the relevant causal roles

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35 On the distinction, see, for example, Cohen, *The Red and the Real*, *op. cit.*, section 7.2. QSF is not, however, functionalist in any teleological or adaptive way. See also, for instance, *ibid.*, pp. 179–80. The view is functionalist only insofar as colors are characterized by their causal roles—in particular, in causing particular discriminatory behaviors.

36 See, for example, David Lewis, "How to Define Theoretical Terms," this JOURNAL, LXVII, 13 (Jul. 9, 1970): 426–46.

37 The fact that colors are arguably realized by SSRs and role-functionally analyzed in terms of their roles in causing visual discriminatory behavior in part explains why views such as color physicalism or color dispositionalism may seem attractive. According to QSF, the physical bases and mental impact of color are relevant to our complete understanding of color, though we should not understand colors fundamentally in those terms.

38 See Cohen, *The Red and the Real*, *op. cit.*, p. 177ff.

39 *Ibid.*, p. 178, emphasis his.

are the properties of disposing the bearers of colors to look certain ways to particular perceivers under certain conditions, whereas for QSF the relevant roles are identified and individuated via locations within the color space.

Unlike relationalism, which is plainly a mind-dependent theory, QSF arguably characterizes colors mind independently. Though many varieties of functionalism describe their *explananda* in mind-dependent ways, not all functionalisms concern properties constitutively tied to mental states. Bottle openers are plausibly role-functional kinds characterized by their roles in opening bottles; although bottle openers would be of interest to (or used by) only minded creatures with certain intentions to open bottles, we can characterize them functionally without reference to such creatures or mental states. According to QSF, we can characterize colors solely by their locations within the color space, without reference to mental states as such. QSF does not, however, regard the colors as (first-order) dispositions to cause particular mental states—and thus does not amount to a version of color dispositionalism. Just as the properties of *being a bottle opener* or *being a desire* can be understood functionally by reference to their causal impact on bottles or other mental states, while not entailing that they are dispositional properties, colors are categorical features of objects understood functionally.[40]

QSF and Cohen's relationalism differ in other ways too. Perhaps most saliently, Cohen's view is *atomist* insofar as the relevant functional roles characterize each color individually, making no reference to other colors (hence his '*mutatis mutandis*' above). On Cohen's view, it is metaphysically possible that there be a world in which there is, and could be, only one color. But, again, QSF is quasi-holistic insofar as the functional roles that characterize colors invariably involve other colors.

This feature of QSF may, however, seem to expose it to a serious objection. We recall that it is a constraint on an adequate theory of color that it fit with color phenomenology. And one might object that QSF is unworkable because colors appear to be intrinsic features of objects—and so it may seem that colors do not experientially appear to be holistically individuated in the way that QSF holds. We can, for example, see individual colors—as in an experience of so-called 'ganzfeld' wherein one's visual field is completely filled with a single color—which may seem to suggest that color phenomenology is atomistic. Jesse Prinz has urged that such experiences undermine QSS,[41] but they may also seem to undermine QSF.

I have argued elsewhere, however, that such considerations do not threaten QSS[42]—and this objection likewise does not undercut QSF. It is far from obvious that color experiences present colors as intrinsic properties as opposed to holistically individuated ones. That we can see only single colors at a time, for example, may lead one to *theorize* that colors are intrinsic properties, and such (background) theorizing may come to seem intuitive, but the fact that we can see colors alone does not count against QSF's claim that colors are holistically individuated. Since this space reflects creatures' dispositions to engage in discriminatory behavior, the space can individuate the colors whether or not colors are perceived together, alone, or even ever perceived at all. Moreover, introspection seems to suggest that colors are instead holistically individuated. When asked to describe the colors that one is visually experiencing, one naturally responds by characterizing them

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40 One might nonetheless object that, while colors are on this view not mind dependent, they are still *system dependent* insofar as the color space depends on features of the discriminatory systems of creatures. It is thus a delicate issue as to where the view stands on the issue of mind (in)dependence. I would say that the view stands on a knife's edge between these positions—and it is not clear what hangs on settling the issue because, as we shall see, many views, including standard versions of physicalism, have similar consequences. The view is nonetheless plainly realist. While it may be that we would not be *interested* in the colors as functional kinds if we did not have the visual systems that we in fact have, such properties would exist whether or not such visual systems exist.

41 Prinz, *The Conscious Brain*, *op. cit.*, p. 132.

42 Berger, "A Defense of Holistic Representationalism," *op. cit.*, p, 166.

comparatively—that is, in terms of their relations to one another—which at least suggests that such properties are holistically described.[43]

II. QSF'S BALANCING ACT

There are many reasons to prefer QSF to standard theories of color already in the literature, but at this juncture I mention only a few of these. Overall, I urge that QSF's functionalist nature better balances the tension in our commonsense conception of color between our ordinary impression, which pushes some toward mind-dependent theories, that colors in some way depend on us and the impression, which pulls toward mind independence, that colors are interpersonally available physical properties.

To appreciate the issue, consider the well-known experimental finding regarding *metamers*, or pairs of stimuli that look to be the same color under the same viewing conditions, but that are nonetheless physically quite different (for example, different SSRs). Some urge that the mere existence of metameric pairs undermines mind-independent views such as color physicalism and supports color eliminativism.[44] The basic thought seems to be: how could colors be ordinary physical properties if they seem so dependent on how they appear to us?

But eliminativism contradicts common sense and is in any case unnecessary. QSF straightforwardly explains metameric pairs, without denying the existence of colors. As a role-functionalist view, QSF holds that physically disparate stimuli discriminated as occupying the same location within the discriminatory space are identified as the same color. If the pair SSR 1 and SSR 2 are discriminated as occupying the same location within the color space, then QSF regards both SSRs as realizers of the same color.

Some physicalists attempt to accommodate metamers by adopting more complex versions of the view. Some physicalists, for example, propose that colors are identical with *types* or *disjunctions* of physical properties.[45] But such versions of physicalism thereby face an obvious problem: they hold that the colors are purely physical but quite gerrymandered properties—and the only thing that would seem to explain their gerrymandered nature is their effects on creatures' discriminatory behavior or visual systems. On such views, for example, the colors are (sets of) SSRs, which simply *happen to be* indiscriminable by normal observers under normal circumstances or which stimulate equivalent ratios of retinal activations in normal human beings.[46] Color physicalists maintain that this aspect of their view does not, however, render the colors mind dependent. Some color physicalists urge that considerations such as the impact that physically disparate properties have on creatures' visuals systems serve only to fix the referents of our color terms, though such relations do not characterize colors' fundamental physical natures.[47] Others maintain that, while we would not be *interested* in such properties if we were not to have the visual systems that we have, such properties are nonetheless purely physical.[48] But while such views do not explicitly build mentality into the nature of the colors, they do not satisfyingly explain the *anthropocentric* character of the colors—

[43] See, for example, Rosenthal, *Consciousness and Mind*, *op. cit.*, pp. 204–05.
[44] See, for example, Hardin, *Color for Philosophers*, *op. cit.*; Isaac, "Structural Realism for Secondary Qualities," *op. cit.*
[45] See respectively, for example, Byrne and Hilbert, "Color Realism and Color Science," *op. cit.*; and Ross, "Fitting Color into the Physical World," *op. cit.*
[46] See, for example, Byrne and Hilbert, "Color Realism and Color Science," *op. cit.*, p. 10.
[47] See, for example, Ross, "Fitting Color into the Physical World," *op. cit.*, p. 591.
[48] See, for example, Tye, *Consciousness, Color, and Content*, *op. cit.*, p. 161.

namely, why creatures' visual systems or other factors would play such roles in picking out the referents of such putatively purely physical predicates.[49]

Mind-dependent views, by contrast, accommodate metamers by explicitly building mentality into the nature of color. Recall Cohen's relationalist functionalism, which individuates colors in terms of their roles in eliciting certain color appearances under particular circumstances. Or consider ordinary varieties of dispositionalism, according to which colors are identified with the dispositions (or categorical bases of such dispositions) to cause certain color appearances. Like QSF, such views make no assumption about the underlying physical nature of the relevant dispositions or *relata*.

A well-known problem for such views, however, is that they thereby require an independently motivated account of what it is for a color to look a certain way. And since there is much debate about how to explain such visual appearances, a central worry for standard mind-dependent theories is the threat of circularity.[50] This is because many theories of visual content explain perceptual appearances *in terms of* colors—and not the other way around. This is plainly the case for a theory such as QSS. Likewise, on so-called 'tracking theories' of perceptual content such as Tye's theory mentioned above, it appears to a subject *S* that a color *C* is present just in case *S*'s visual state stands in the appropriate tracking relation—for example, suitable causal covariation under optimal conditions—to *C*. If such views were true, then we could not hold that colors are to be explained in terms of how they appear, lest the accounts be uninformative. It is common for proponents of mind-dependent theories to attempt to avoid this circularity by individuating visual appearances in ways that do not invoke colors—for example, by invoking relations to nonphysical qualia or to neural states of particular types.[51] But without some independently motivated account, the unattractive possibilities of circularity or the rejection of naturalism loom large.

QSF sidesteps these issues altogether, splitting the difference between the extremes of standard mind-independent and mind-dependent views. QSF explains why and how our realist account of color makes reference to observers, without building minds into the nature of color. And though QSF may seem to be a variant of disjunctive physicalism, it is not. In his critique of Peter Ross's version of disjunctive physicalism, Rosenthal observes:

> [T]he color an object looks to us to have is a function not of the spectral reflectance itself, but of the ratio of activation of those three light-sensitive elements that the spectral reflectance results in…. One cannot, accordingly, identify the colors of physical objects with spectral reflectances, since objects we count on commonsense grounds as having the same color have different spectral reflectances. These considerations do not, however, preclude identifying the colors of physical objects with suitable *ratios* of the reflectance properties of visible objects. Physical color properties are equivalence classes of reflectance properties, where the defining equivalence relation is specified in terms of such ratios…. Taking standard illumination as fixed, the ratios in question correspond one-to-one to commonsense colors; they are in no way disjunctive. Of course, each color corresponds to a range of reflectance profiles, but that is because each ratio can result from a range of reflectance profiles. Whether some property is disjunctive often depends on the level of analysis from which we approach it. The physical properties we identify colors with are disjunctive if we take specific reflectance profiles as basic, not if we take ratios as basic.[52]

Although Rosenthal casts things here in terms of SSRs' propensities to cause equivalent ratios of retinal activations, it would again seem open to regard colors as multiply realizable by members of

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[49] See, for example, Rosenthal, "Color, Mental Location, and the Visual Field," *op. cit.*, pp. 86–87; and Gow, "Colour," *op. cit.*, p. 806.
[50] See, for example, Byrne and Hilbert, "Are Colors Secondary Qualities?," *op. cit.*, section 2.1.
[51] See, for example, Cohen, *The Red and the Real*, *op. cit.*, section 6.4, especially pp. 170–71.
[52] Rosenthal, "Color, Mental Location, and the Visual Field," *op. cit.*, pp. 86–87; see also, for example, Rosenthal, "Quality Spaces and Sensory Modalities," *op. cit.*, p. 41.

sets of properties that simply elicit equivalent discriminatory behaviors. At one level of analysis—call it the 'scientific' or 'physical' level—a particular instance of a color may be realized by a particular SSR; at another level of analysis—call it the 'commonsense', or role-functional, level—the color is identical with the higher-order property of the relevant set of properties, whatever they may be. Naturally, no one would assume that there must be anything physically in common among bottle openers, as bottle openers are functional kinds. Likewise, QSF explains why colors would seem to be gerrymandered insofar as they are role-functional properties, characterized by how they are visually discriminated.

Moreover, according to QSS, a creature's color space simply determines its color-visual space, which in turn characterizes that creature's color appearances. The package of these two views is appealing for many reasons,[53] not the least of which is that it permits an explanatory account of both colors and color content—an account which effectively grounds both color and color content in terms of observable visual discriminatory behavior and thereby respects naturalism.

There may seem to be a decisive consideration against QSF, however—namely, the evidence of perceptual variation—and it is to this issue that I now turn.

III. Perceptual Variation

As an illustration of such variation, I mention briefly three kinds of evidence.[54] Consider first an example of *intrapersonal* variation: so-called 'color-context effects', wherein the way a particular surface visually appears depends on the colors in its surround. A particular color patch might appear to be a light gray if surrounded by a dark-gray border, whereas a physically identical patch might appear to be dark gray if surrounded by a light-gray border. Second, consider an example of *interspecies* variation: the fact that pigeons, for example, have four kinds of color-sensitive retinal cells as compared to the three kinds possessed by normal humans, a fact which entails that there are colors that pigeons but not humans are able to discriminate visually. Third, the existence of ordinary red-green colorblindness in humans is a straightforward example of *interpersonal* perceptual variation.

III.1. Variation and Standard Theories of Color. Perceptual variation plausibly does pose a problem for many theories of color, such as standard versions of color physicalism, because such views often require that an ordinary object exhibit one color only. And this in turn entails that some perceivers may thereby systematically misperceive objects' colors, though it may seem arbitrary to decide which groups so misperceive. In attempting to determine which color an object "really is," there may seem to be no grounds for preferring one set of viewing conditions over another (for example, the dark-gray versus light-gray border) or one kind of visual system over another (for example, pigeons' tetrachromatic versus humans' trichromatic vision). Some physicalists seem to simply bite this bullet, urging that some groups of normal perceivers can and do systematically misperceive the colors.[55]

A perhaps more common way that theorists attempt to accommodate variation, however, is to endorse a form of *color pluralism*, on which a particular object may exhibit infinitely many colors.[56] Physicalists might urge that different sets of creatures may accurately see different sets of colors, as determined, for example, by ratios of activations of the relevant creatures' color-sensitive cells. Likewise, Cohen's relationalism is pluralist insofar as it maintains that creatures in all of these

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[53] See, for example, Rosenthal, "How to Think about Mental Qualities," *op. cit.*; and Berger, "A Defense of Holistic Representationalism," *op. cit.*

[54] For these and other examples, see, for example, Cohen, *The Red and the Real*, *op. cit.*, p. 20ff.

[55] For example, Michael Tye, "The Puzzle of True Blue," *Analysis*, LXVI, 3 (July 2006): 173–78, at p. 174.

[56] For an overview, see, for example, Gow, "Colour," *op. cit.*, pp. 809–10.

situations accurately see objects' colors because objects are multiply colored and accurately represent the relational colors that their visual systems make available to them. Or one could simply endorse pluralist primitivism.[57] These sorts of pluralist views nonetheless face difficulties, including ones mentioned previously.

Perceptual variation may seem to undermine QSF in a more direct way. Such data seems to reveal that many creatures have different discriminatory spaces; one might wonder how QSF can appeal to *the* color discriminatory space that individuates the colors. In the next section, however, I argue that QSF instead provides a better explanation of variation than other standard accounts of color.

III.2. QSF and Variation. Let us first consider cases of intrapersonal variation such as color-context effects. QSF offers a way to determine the color of such patches that is not unacceptably arbitrary. Any quality space must, of course, be indexed to a set of perceptual conditions that obtain at a given time. This is because creatures are plainly able to discriminate colors differently under different lighting or perceptual conditions. It is thus implicit in the description above that "the" space of colors—the *standard* space—is the space of colors indexed to *standard* viewing conditions and *normal* perceivers: something like ordinary daylight against a neutral background perceived by healthy adult human beings who are concentrating and not visually impaired as measured by standard tests of visual acuity. These restrictions are not unfounded. Folk psychology—not to mention much philosophical theorizing—holds that red things are those properties that are distinguishable as red to normal perceivers under standard viewing conditions.[58] And on this view, the color patch that looks dark or light depending on its surroundings will occupy a particular location within the color space when viewed under standard conditions by normal perceivers.

Many theorists have urged, however, that there is no way to determine what counts as standard or normal in the science of color vision that is not arbitrary or underspecified.[59] Discussing as an example the Munsell Color System, Cohen observes that while the instructions specify many of the conditions, including that "the samples should be placed against a dark achromatic background and colors should be arranged under North Daylight or scientific daylight," the instructions "ignore many factors which generates further instances of perceptual variation: for example, they say nothing about the state of adaptation of the subject."[60]

Other theorists have, however, proposed ways to determine standard viewing conditions in what may seem to be a suitably principled way. In defense of his version of color primitivism, for example, Keith Allen proposes that standard conditions are those under which "the spectral power distribution that reaches the eye is (more or less) isomorphic to the surface reflectance profile of the material object."[61] These conditions are reasonable on the assumption that colors at least supervene on their SSRs. And these conditions turn out to be something like the ordinary conditions mentioned above.

QSF suggests another way to index the standard color space. While common sense holds that there are colors that some people cannot visually discriminate (colorblind individuals, for example), it does not hold that people can visually discriminate features of objects that are not colors or marked by color boundaries.[62] It is thus reasonable to maintain that the color space is the map that represents creatures' *maximal* capacities to discriminate among colors via vision—that is, the

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[57] This is the view defended in, for example, Gert, *Primitive Colors*, *op. cit.*
[58] See, for example, Sellars, *Science, Perception and Reality*, *op. cit.*, chapter 5.
[59] See, for example, Hardin, *Color for Philosophers*, *op. cit.*, p. 67ff.
[60] Cohen, *The Red and the Real*, *op. cit.*, pp. 34–35.
[61] Keith Allen, *A Naïve Realist Theory of Colour* (Oxford: Oxford University Press, 2016), p. 54.
[62] We naturally can visually discriminate noncolor properties such as shapes, but we cannot see such properties without also seeing the colors that mark their boundaries.

space that captures the most differences between the colors.[63] Whatever viewing and perceptual conditions enable creatures to maximally discriminate among the colors are the normal viewing conditions. These conditions will likely be the conditions that Allen specifies, although this proposal fits more with common sense than Allen's view, insofar as it makes no assumptions about the underlying (physical) nature of color—and also leaves open that there may be radical cases wherein objects' physical features in no straightforward way match how they engender discriminatory behavior.

What about cases of interpersonal variation, such as instances of ordinary colorblindness? Since QSF holds that the relevant color spaces are generated by creatures' visual discriminatory capacities, and since visual discriminatory capacities vary from one creature to another, it must be the case that each creature will have its own color quality space indexed to that creature under standard viewing conditions.[64] So, again, one might worry that there are no principled reasons to count certain individuals as normal.

But such considerations are no problem for QSF because it is plain that any functionalist account must take into account individual differences between instances of its *explananda* to offer a general account of the phenomenon. No two bottle openers will open bottles in *exactly* the same way—and yet we have no trouble functionally characterizing two physically distinct bottle-opener-shaped objects as bottle openers. QSF similarly holds that the standard discriminatory space of colors is generated by a process akin to averaging over the color spaces of all of the individuals in the relevant group to determine the space that reflects the maximal capacity of creatures in that set to discriminate among the colors. The relevant group will likely at least include normal adult human perceivers with no visual impairment. And the process of collating spaces will likely involve the technique of *multidimensional scaling*, wherein data from many individuals can be scaled to capture the relative similarity-and-difference measures of the cohort.[65] If, for example, the best way to generate the discriminatory space is via a JND method, such scaling could be accomplished by interpersonal comparisons of relative similarities and differences as measured by numbers of JNDs—a distinct advantage of this approach.

Whether or not there is an effective way to determine the standard space, Cohen argues that such a standard would be problematic because it would "commit one to the unpalatable conclusion that the color discriminations of most (perhaps as many as 90% of) human visual systems are erroneous."[66] Folk psychology does, however, admit of some cases wherein individuals systematically misperceive or "miss out" on various colors. It is reasonable to claim that a person with a standard kind of red-green colorblindness systematically misperceives red objects as yellow under ordinary viewing conditions. The combination of QSF and QSS explains this result. According to QSS, assessments of perceptual accuracy are accomplished by comparing locations within an individual's color space to their respective locations within the standard color space to characterize those locations as, for example, the yellow regions or nodes. This will likely use the mathematical process of constructing *homeomorphisms*, which are continuous functions that map two geometrical spaces onto one another while maintaining the topological features of both spaces.[67] The view thereby explains our colorblind individual's misperception, holding that she locates the

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[63] This is similarly proposed by Young, Keller, and Rosenthal, "Quality-Space Theory in Olfaction," *op. cit.*, p. 7.

[64] Indeed, such individual spaces must be indexed to time-slices of individuals because perceptual discriminatory capacities may change, thereby altering one's quality space, due to various factors such as perceptual learning or intoxication. *Ibid.*, p. 3.

[65] See, for example, Clark, *Sensory Qualities*, *op. cit.*, pp. 100–01.

[66] Cohen, *The Red and the Real*, *op. cit.*, p. 32.

[67] See, for example, Berger, "A Defense of Holistic Representationalism," *op. cit.*, p. 173.

relevant objects in yellow regions of her color space, even though the objects occupy red locations within the standard space.

One might object, however, that the fact that QSS holds that color perception is holistic rules out that individuals with colorblindness are able to see *any* of the colors that those without visual impairment are able to see. That is, one might worry that if a colorblind person cannot see red, then she cannot see yellow, or any other color for that matter, either. But QSS's claim that one's ability to see a particular color requires one to be able to see a host of colors does not require that one be capable of seeing all or even many colors *accurately*. For an individual to be able to see yellow, she must be able to visually represent other colors such as blue—she must be able to distinguish stimuli as having locations distinct from *her* yellow location—though she need not locate those stimuli in the locations that they occupy in the standard space. Determining *how* one visually (mis)perceives stimuli is then a matter of comparing the way one organizes her individual color space to the organization of the standard space.

This view does entail that many or even all perceivers typically misperceive the colors to some extent—a conclusion that Cohen and others may still find implausible. But this kind of systematic misperception is not problematic.[68] First, as several theorists have recently urged, there arguably are many cases of ordinary or systematic perceptual misrepresentation across a variety of contexts: in criticizing tracking theories of perceptual content, for example, Brian McLaughlin cites the experimental finding that ordinary perceivers under clear lighting conditions typically see squares as taller than they are wide.[69] The idea that many or even all color perceivers misperceive colors to some extent may thus not be so unpalatable—a conclusion some theorists are already prepared to accept—or even special to color perception.

Second, as Allen observes, much of the experimental evidence that purports to demonstrate widespread interpersonal variation is overblown; disagreements about objects' colors arise rather infrequently—and usually concern only fairly determinate colors, not objects' determinable colors.[70] QSF reveals why this would be the case. Just as any ordinary functionalism permits us to abstract away from irrelevant differences, small deviations from the norm will be observable, but for practical purposes can simply be ignored. Certain regions or nodes may be sufficiently similar to regard as the same—or at least to regard as of the same determinable color.

Indeed, QSF can even accommodate more extreme examples of interspecies variation because, like many theories of color, it too fits with a theoretically flexible kind of color pluralism.[71] Consider the case of tetrachromatic pigeons. Whether or not we count ordinary human beings as able to see only a subset of colors that pigeons can see depends on whether or not we include pigeons within the set of individuals that generate the standard space of colors. If we do count pigeons within the set that includes normal adult human beings, then we might regard humans as simply unable to see certain colors. That is, there may be realizers of particular colors that make impressions on only some visual systems, analogous to the way that we ordinarily regard normal adult human beings as unable to see ultraviolet, although there are some creatures that can. And while we typically do not regard ultraviolet as a color that human beings cannot see, QSF leaves open that we might make that theoretical choice.

The decision to include kinds of creatures within a cohort, and thus to delimit the color space in particular ways, depends on various theoretical factors, such as considerations of visual-

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[68] See *Ibid.*, section 5.2.

[69] Brian McLaughlin, "The Skewed View from Here: Normal Geometrical Misperception," *Philosophical Topics*, XLIV, 2 (Fall 2016): 231–99, at p. 282.

[70] Allen, *A Naïve Realist Theory of Colour, op. cit.*, section 3.3.

[71] See also, for example, Berger, "A Defense of Holistic Representationalism," *op. cit.*, section 5.2.

system individuation (for example, whether or not pigeons' visual pathways are sufficiently similar to humans') and niche individuation (for example, whether or not pigeons' environments are sufficiently similar to humans'). It may also include factors about the relative comparability or overlap of the geometries of those cohorts' spaces.

Since pigeons have quite different visual systems than ordinary human beings, we may make the theoretical choice to individuate the properties that they see via their eyes as generating a standard space not of the kind of colors that humans see, but of the kind of colors visible to pigeons. We might call the former 'human-colors' and the latter 'pigeon-colors'. A role-functionalist view such as QSF is, of course, compatible with the same physical properties (for example, SSRs) realizing distinct kinds of role-functional colors. In that case, a pigeon might accurately see a particular color realizer as playing a pigeon-color role, but not a human-color role—that is, see it as a pigeon-color and not a human-color—just as we regard colorblind persons as able to misperceive particular human colors as other human colors. Here, it is not that colorblind persons cannot see a particular realizer in the way that humans cannot see ultraviolet, but they cannot see certain realizers as playing particular color roles. This view constitutes a modest variety of *selectionism* about color, wherein our sensory systems enable us to select among the (limited) set of colors that objects exhibit.[72]

To further illustrate the view, consider the following case involving two perceivers: Tanya, who has ordinary trichromatic vision, and Dana, who is dichromatic and so experiences a form of red-green colorblindness.[73] As a result of Dana's condition, her individual discriminatory space will be a reduction of Tanya's individual space, insofar as Dana is incapable of discriminating stimuli that Tanya can discriminate. And suppose there are two stimuli, S_1 and S_2, which occupy the same location in Dana's discriminatory space but different locations in Tanya's space. Are S_1 and S_2 the same color?

According to QSF, the answer depends on how we decide to individuate the colors; this decision, again, depends on various theoretical considerations. We could, for example, maintain that dichromats have access to a different set of colors than trichromats, in which case S_1 and S_2 are the same dichromat-color, though different trichromat-colors. But this view is implausible for several reasons. Among other things, Tanya and Dana are members of the same species and there is much geometrical overlap between their discriminatory spaces. If, by contrast, Dana were a member of an alien species, we might be inclined to hold that she accurately perceives her species' own set of colors. But as Dana is by hypothesis human, perhaps it would be better to hold that she visually misrepresents S_1 and S_2 as the same color, when in fact they are different colors. Presuming Tanya's individual discriminatory space matches the standard discriminatory space, perhaps Tanya accurately sees S_1 as red and S_2 as yellow, though Dana inaccurately sees both as yellow. In that case, Dana systematically misperceives the colors to some extent. But, as I have argued, such widespread mild visual misperception is unproblematic and even to be expected.

III.3. QSF, Color Relationalism, and Variation. In closing this section, I mention an additional reason to prefer QSF's account of perceptual variation to Cohen's functionalist variety of color relationalism, a consideration which I have briefly noted elsewhere.[74] Although relationalism may seem ideally suited to explain perceptual variation, the view has problematic implications regarding the possibility of misperception. Since Cohen's account claims that an object always has the relational color property that it appears to have under those viewing conditions, this view entails that creatures are unable to visually misrepresent objects' (relational) colors. This consequence plainly

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72 On selectionism, see also, for example, Allen, *A Naïve Realist Theory of Colour, op. cit.*, p. 66ff.

73 I thank a referee for this JOURNAL for encouraging me to work through this example.

74 See Berger, "A Defense of Holistic Representationalism," *op. cit.*, p. 174, fns. 21 and 23.

violates folk psychology, which holds that individuals can and often do misperceive colors. In reply, Cohen proposes that we can taxonomize colors in two ways: although perceivers cannot misrepresent colors characterized in a *fine-grained* way, relative to individuals in particular circumstances, they can and often do misrepresent the colors understood in a *coarse-grained* way, relative to groups in particular circumstances (factors which are determined in contextual and fluid ways).[75]

QSF nonetheless strikes a more commonsense balance than color relationalism between our ordinary impression that colors in some way depend on us and the impression that colors are interpersonally available and thus capable of being misperceived. QSF and QSS together similarly offer us two ways to taxonomize visual states' contents, depending on how we taxonomize colors. Assessing the accuracy of visual states relative to the standard space of colors is not the only way of assessing such states' contents. We may also consider colors as they are individuated by individuals' *own* spaces—in which case we can say that perceivers need not systematically misrepresent colors, even to some slight degree. If one is in a visual state *S* that matches the location of color *C* in one's own space of colors, and *C* is present, then *S* may accurately represent *C*. But QSF permits visual misrepresentation of colors, even when they are taxonomized relative to individuals. If I am in visual state *S* corresponding to *C* in my own color space, but *C* is not instantiated, then I misperceive.

The theoretical function of assessing individuals' color visual states relative to their particular color spaces is to explain how and why creatures navigate their environments as they do; the theoretical function of assessing such states relative to the standard space is to taxonomize the properties visually represented as being particular colors—to determine whether individuals see the colors "as they are." However it is that we assess color visual states, the combination of QSF and QSS can account for the diversity of accurate color perception across individuals and species.
I have motivated and defended here a functionalist theory of colors, which I have called 'QSF'.

IV. Conclusions

I have argued that QSF best captures our commonsense conception of color, fits with many experimental findings, coheres with the phenomenology of color experience, and avoids many issues for standard theories of color. It is realist, compatible with naturalism, and enables the theoretical flexibility to account for widespread perceptual variation. Although many details of this theory still need to be filled out, QSF should be considered as a promising alternative to other mainstream theories of color.

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[75] Cohen, *The Red and the Real*, *op. cit.*, p. 128ff.