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11

NOVEL COLOUR EXPERIENCES AND THEIR IMPLICATIONS[1]

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> One evening, in summer, he went into his own room and stood at the lattice-window, and gazed into the forest which fringed the outskirts of Fairyland … Suddenly, far among the trees, as far as the sun could shine, he saw a glorious thing. It was the end of a rainbow, large and brilliant. He could count all seven colours, and could see shade after shade beyond the violet; while before the red stood a colour more gorgeous and mysterious still. It was a colour he had never seen before.
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> *From George MacDonald (1867) "The Golden Key" in his Dealing with the Fairies, London: Alexander Strahan, pp. 250–1*

In his writings for children, George MacDonald (1867) portrays the exhilaration and wonder that would likely accompany experiencing beautiful colours that one has not experienced before. One reason it would be exciting, I proffer, is that we tend to think that we have experienced all the colours that we can experience, and the idea that there are other colour experiences to be had seems rather far-fetched. It is no coincidence that MacDonald's protagonist experiences the novel colours in Fairyland.

Part of the reason that the idea of experiencing novel colours seems a remote possibility is that most people report that they cannot visually imagine what it would be like to experience colours other than those they have already seen.[2] Contemplation of such experiences cannot be done by conjuring up images in the mind's eye of unfamiliar colours but, instead, is limited to a rather abstract contemplation of the fact that there could be such colours. This, no doubt, contributes to the sense of mystery that MacDonald invokes in his description of the colours of Fairyland.

For philosophers, the question of whether there could be experiences of colours that you have not experienced before is an exciting one for additional reasons. The existence of such colour experiences promises to substantially inform our theories of colours and colour experiences. It is therefore of great interest that some psychologists have recently claimed to create experiences of new colours.

This chapter explores the evidence for the existence of such new colour experiences and what their philosophical ramifications would be. I first define the notion of 'novel colours' and discuss why I think that this is the best name for such colours, rather than the numerous other names that they have sometimes been given in the literature. I then introduce the evidence and arguments for thinking that experiences as of novel colours exist, along with objections that people have had to that evidence and to those arguments. To do so, I outline some facts about ordinary, non-novel colours before considering whether experiences as of novel colours, exist. Then I discuss the potentially significant ramifications the existence of novel colour experiences would have for theories of the metaphysics of colour, theories of the nature of colour experience, and for theories of the nature of perception more generally.

1 What are novel colours and what should we call them?

When we contemplate experiences of colours that an individual has not had before, we have to take into account the fact that different people have different colour experiences. Colour blindness exists in many forms. If a person had a form of colour blindness that meant that they experienced all the colours that someone who was not colour-blind experienced except for the fact that they did not experience any shades of red, it would likely be very exciting for him or her, personally, if we could circumvent their colour blindness and give them an experience of red that they had not had before. However, from an impersonal, philosophical point of view this would not be a particularly interesting occurrence. We typically think that the colour red exists (if any colours do) and experiences of it are ubiquitous, even if not had by everyone.

What is really interesting, from a philosophical point of view, is whether there are experiences of hues of colour in addition to those that the standard colour theory says that humans (with what is defined to be "normal" tri-chromatic vision[3]) have in standard viewing conditions. If there are such experiences, as I hereby define them in this essay, there are experiences of 'novel colours'. Evidence from a wide variety of sources has been adduced to support the existence of experiences as of novel colours.

One thing to note about this definition of novel colours is that there is a lack of precision in it. What counts as standard viewing conditions? Different theorists offer different accounts of these. However, I don't think that we need to choose between these, or that we need be overly concerned by the vagueness that thereby remains in the definition. In almost all cases that I will examine, the conditions for experiencing novel colours fall well outside of the broad range of everyday viewing conditions: those that occur on account of detecting reflected light in the standard sorts of environments that humans typically view objects. And in those cases that are less clear cut, we can simply note that they are so, and note that whether the term 'novel' colours applies in these cases is less clear cut too.

The reason for focusing on hues of colour in this definition, rather than just colours, is that not everyone thinks that the standard colour theory captures all of the colours. For example, Saunders and van Brakel (1997) claim that the standard colour theory fails to capture properties like glossiness, lustre, sparkle, glitter, insistence, pronouncedness, brilliance, fluorescence, glow, iridescence, and colourfulness. They believe that some colours have these properties and thus they fall outwith the colours described by standard colour theory. By focusing my definition of novel colours so that it requires that they be novel hues of colours, compared to that which the standard colour theory holds there to be (in humans with normal trichromatic vision in standard viewing conditions), I want to define novel colours as properties besides those which standard colour theory says exists, but also besides the colours that have the properties that Saunders and van Brakel claim exist—which are properties that are commonplace and ubiquitously experienced by people. The novel colours that are discussed by philosophers and psychologists certainly are ones that fall outwith standard colour theory, but they are also taken to be ones that fall outwith the further list of colours and colour properties that Saunders and van Brakel take to exist.

I will take it that it does not follow simply from the fact that there are experiences of novel colours that novel colours themselves exist. This is on account of two related facts. First, to make a metaphysical stipulation, I will take it that for novel colours to exist in the actual world—or in a possible world—those colour properties have to be instantiated (at least at some point in time) in the actual world—or the possible world.[4] Second, I take it to be a possibility that experiences of novel colours could be always non-veridical and purely illusory or hallucinatory. Nonetheless, the existence of experiences as of novel colours, particularly when held together with the view that at least some colours exist, will sometimes provide evidence that novel colours exist. If there are such colours, they would fall outwith the classic colour space as defined by opponent process theory.

Other names besides 'novel colours' have been used to refer to these colours whose existence we are contemplating. They have been referred to as 'impossible',[5] 'forbidden',[6] 'alien'[7] 'Martian'[8] and 'chimerical'[9] colours. I believe that we have good reason to use the term 'novel', rather than any of these alternatives. I dislike the use of the first four of the alternative names as they are misleading in one way or another, while the fifth name properly refers only to a subset of novel colours.

I disapprove of the adjective 'impossible' to describe novel colours as it is a question of substantive philosophical debate what the modal status of novel colours is. Whether such colours are actual, or whether they are nomologically, metaphysically, conceptually, or logically possible or impossible is therefore not a matter to be stipulated by fiat. This is particularly the case because what one takes the modal status of novel colours to be will be highly dependent on the details of the theory of colour one holds to be true. For example, sense-data theorists hold that, when one has a perceptual experience as of an object having a property, there always exists a mental object that really does have that property. Sense-data theorists will therefore think that novel colours exist (in the sense of being instantiated) just so long as experiences of novel colours exist, because they will take them to be instantiated properties of sense-data. In contrast to this, if one thinks that colours are surface reflectance properties of physical objects, and if experiences of novel colours do not correspond in the right way to any surface reflectance properties then the mere existence of such experiences would not guarantee the existence (that is the instantiation) of novel colour properties. Whether, on this view, we should think of novel colours as nomologically impossible, or also as metaphysically impossible, will depend on one's further commitments. Given that there is no consensus on which theory of colour is correct, it is at least premature, and certainly biased in favour of some theories of colour at the expense of others, to label novel colours 'impossible'.

I am also not in favour of calling novel colours 'forbidden'. The only things that, plausibly, might 'forbid' them are certain theories of colour—theories that rule out the existence of such colours or colour experiences. However, as I have explained above, it is a matter of ongoing debate which theory of colours we should adopt so, again, I believe that it is best not to label these colours in a way that prematurely seems to take a stance on a debate that is as yet unsettled.

I also have an aversion to calling novel colours 'alien' or 'Martian'. These terms are often used when people are referring to the novel colours reported by some people who experience synaesthesia.[10] However, in every instance that these synaesthetic colours are discussed, the topic is whether terrestrial creatures experience or could experience these colours. There is no discussion of whether these colours exist on Mars or other alien locations within our universe or are experienced by alien creatures with a physiology unlike ours—a physiology that could not exist on Earth. So, these names are rather misleading.

In contrast to these other names for novel colours, the term 'chimerical' colours has, following Paul Churchland (2005), come to be used to refer to a distinct class of novel colours. These are colours that fall outside the classic colour space as defined by opponent process theory and that it is claimed can be experienced by inducing coloured after-images in a particular way. The after-images are induced by prolonged fixation on a colour stimulus and then by subsequent experiencing the after-images projected on a particular coloured background.[11] 'Chimerical' colours is a perfectly good name for this subset of novel colours, and I will use it to refer to that subset, in addition to using the more inclusive 'novel' colours nomenclature. I will discuss chimerical colours at greater length below.

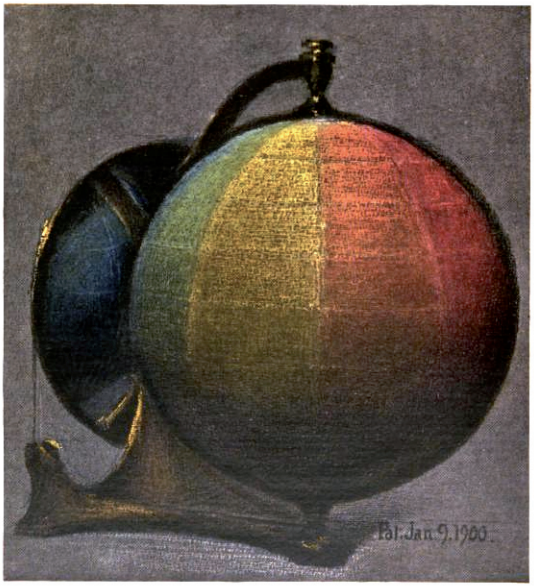
Thus, in light of the above considerations, I will use the term 'novel' colours, to refer to all of the (alleged) colours under consideration and urge others to do the same.

2 The non-novel colours

Before considering novel colours any further, consider the 'non-novel colours'. Those are the colours that humans with normal tri-chromatic vision see just on account of detecting reflected light in the broad range of everyday viewing conditions. These colours are often thought of in terms of their location in a space of relations known as the classical colour space.[12] The three-dimensional space has six basic colour qualities that come in three sets of pairs that form the three axes of the space: black and white, red and green, and blue and yellow. The axes intersect at a mid-grey point.

There are two ways to build a colour space. The first is based on the judgements of subjects about the colours that they make based simply on the appearance of the colours—that is based on what it is like to experience the colours. In more philosophical terminology, the judgements are based on the phenomenal character of colour experience and on the phenomenal nature of the colours. According to the standard account of colour, black and white appear to people to be opposites and not to contain any chromatic colour. Moreover, within the colours it is claimed there are shades of certain colours, namely, black, white, red, green, blue, and yellow, that are unique in that they look to contain no other colours. That is, there are shades of these colours, that look that colour, simpliciter, and not to contain any other colour. For example, there is a shade of black and a shade of white that are unique that don't look to contain grey or any chromatic colour. There is a shade of red that looks not to contain any blue or yellow or green. Apart from these unique shades of colours all the other colours are said to look to contain a mixture of colours and, in particular, all the other chromatic colours look to contain a mixture of two of the four basic chromatic colours—they are said to be binary colours. For example, orange will always look to contain both red and yellow; purple always looks to contain red and blue; aquamarine looks to contain blue and green; and lime green looks to contain yellow and green. In addition, construction of the space uses judgements of resemblances that are noted between colours by a large number of observers. (For example, judgements of the form that orange is more similar to red than it is to green, or that one particular shade of colour is more similar to a second than a third.) The colour spaces that result, such as the Munsell Colour System[13] and the Natural Colour System,[14] model how the colours appear to observers—thus they serve as a model of the phenomenal character of colour experience, even if they are sometimes primarily intended as a model of surface colours.[15] To a first approximation, the colours form a sphere. However, if the space is built so that the distance between colours represents their subjective similarity then they don't form a sphere but an irregular solid or spindle. (See Figures 11.1 and 11.2).

A second way to build a colour space is to start from the details of the physiology of the colour vision system. These details are outlined in Hurvich and Jameson's (1957) theory of colour. Their theory ends up combining the ideas of the trichromatic theory of colour vision



A BALANCED COLOR SPHERE

Figure 11.1 The colour frontispiece from Munsell (1905). Later, Munsell discovered that if hue, value, and chroma were to be kept perceptually uniform, actual surface colours could not be forced into a regular shape. [This figure is in the public domain due to date of publication.]

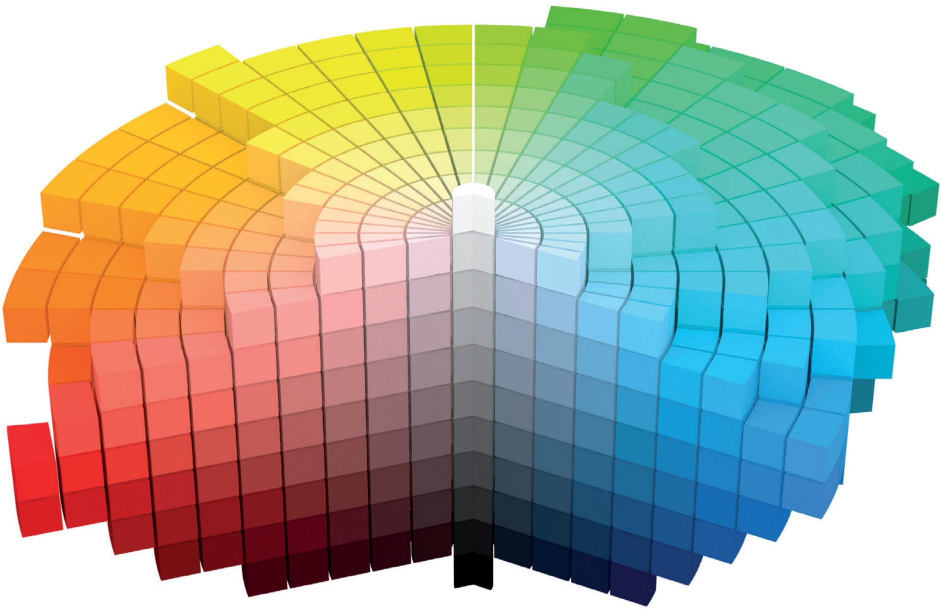


Figure 11.2 The irregular Munsell 1943 colour solid as outlined in Newhall et al. (1943) in which ensuring psychological equispacing of the colours yields an irregular figure. [Image by SharkD [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)]]

propounded by Young (1802) and built upon by Helmholtz (1856, 1860, and 1867), and Hering's (1878/1964) opponent theory of colour. A standard observer's eye contains three different types of cone cell: shortwave, medium wave, and long wave. (A "standard observer" is defined as someone who has the average human's chromatic response.) Inputs to these cells is then combined in various ways to yield three opponent processes: black-white (a lightness dimension), red-green, and blue-yellow (two chromatic dimensions). This means that response to the colour at one end of the dimension is antagonistic to the response to the colour at the other end. This means that detection of red is at the expense of detection of green, and vice versa, and detection of blue is at the expense of yellow, and vice versa.[16] The resulting space is roughly illustrated in Figure 11.3, although details of the modelling that go beyond the scope of this essay reveal it to be slightly more irregular in shape.

What is revealed by these two types of model—each constructed in a different way—is one of the greatest successes of psychophysics. The second way of building up a colour space via consideration of the nature of the colour visual system in the eye and brain yields a space that is isomorphic to the colour space that is built up via consideration of how the colours appear to subjects. The phenomenal facts about the nature of the colours are taken to be beautifully mirrored by, and therefore to be explained, to some degree at least, by the physiological facts. Indeed, this is the best example we have of the phenomenal character of experience—what it is like to have that experience—being apparently explained—at least to some degree—by the physical nature of the brain.

To be precise, it is the structural or relational features of the phenomenal character that seem to be explained—not the intrinsic features, for example the particular quality of the redness of red. An entirely different set of qualities that bore the same structural or relational features to each other would be equally well explained by the physiological facts. However, on account of

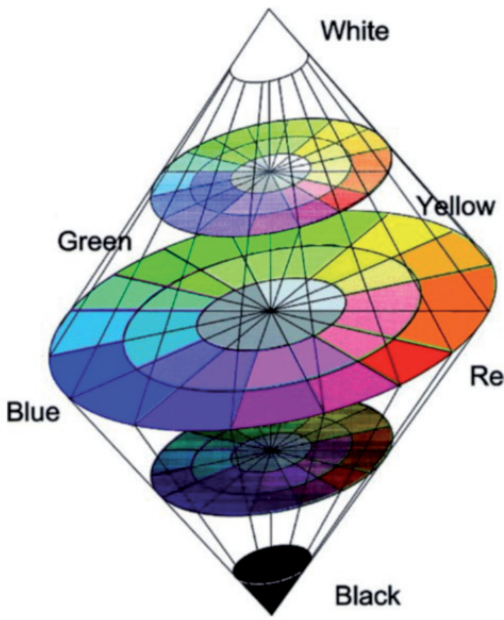


Figure 11.3 Idealisation of the classic colour space as built up from modelling the colour visual system. Taken from Churchland (2005: 531).

the isomorphism, and the fact that it is our colour experiences to which there is this isomorphism, "speculative thoughts of intertheoretic identities [are] likely to be born" (Churchland, 2005: 538). In other words, there is some reason to think that the best and simplest explanation of the isomorphism is that the experiences simply are the relevant states of the visual system. However, this thought will be resisted by many for a large number of reasons: (1) as just mentioned, it is only the structural or relational features that are explained, (2) it is not easy to see how a physical state could be a conscious state, and (3) the numerous reasons well-rehearsed in standard philosophy of mind opposing the reduction of the mental to the physical, such as the potential multiple realization of the mental by the physical.

The colour space—conceived of now as something that reflects both the phenomenal character of colour experiences and the underlying physiology of the visual system—is also taken to explain what many people take to be a fact, namely, that we do not experience binary colours that appear as if they are made up of unitary hues that lie at opposite ends of the two chromatic dimensions of the colour space—that is reddish-green or bluish-yellow colours. The explanation for this on the phenomenal level is that there could be no appearance of reddish–green for that colour does not appear in colour space. To travel from red to green through colour space one either has to go via the central vertical lightness axis where the saturation of the red colour falls to zero and thus becomes grey before taking on greenish hues, or one has to travel by skirting around that axis. But in that case, the red hue will change to blue or to yellow before it takes on green hues. The same goes for bluish-yellow. The explanation on the physiological level is that, in line with the opponent nature of the way in which we detect colour—the fact that when we detect red it is at the expense of green and vice versa, and similarly for blue and yellow, discussed above—provides a reason to think that we could not experience reddish-green or bluish-yellow shades of colour.

Of course, whether or not there can be experiences of reddish-green and bluish-yellow forms a central topic of investigation in this chapter, for whether there can be such experiences forms the main debate about whether there can be novel colours. The question that will concern us is whether it is possible to have such experiences. The explanations I have just outlined explain why it is standardly taken to be the case that there cannot be experiences of reddish-green or bluish-yellow novel colours: the colour space, conceived of as above, predicts that there cannot, in principle, be such experiences.

3 Sources of evidence for experiences of novel colours

There are seven sources of evidence for the existence of experiences of novel colours.

1. Literary Sources
2. Colour Blindness
3. Tetrachromats
4. Chimerical Colours
5. Synaesthesia
6. Filling-In Experiments
7. Painting

I examine each in turn.

3.1 Literary sources

Experiences of novel colours have been referred to in works of fiction. One example is George MacDonald's "The Golden Key" (1867: 251), a quotation from which opens this chapter. He describes a character who is looking towards Fairyland and experiences—indeed sees—a colour that he has never seen before.

Another example comes in the writing of H. P. Lovecraft "The Colour Out of Space" (1927). He describes a meteor strike on Earth that causes things to take on new colours around the area of the impact:

> All the orchard trees blossomed forth in strange colours, and through the stony soil of the yard … No sane wholesome colours were anywhere to be seen except in the green grass and leafage; but everywhere those hectic and prismatic variants of some diseased, underlying primary tone without a place among the known tints of earth.

These examples attest to the thought that we can conceive of the experience of novel colours. Indeed, the authors go further than this. They conceive of the existence of novel colours, not merely experiences of such. This is because the experiences of the protagonists are conceived of as veridical. According to MacDonald, Fairyland really does contain new colours, and according to Lovecraft, the meteor really has caused things to really take on a new "primary tone". Thus, they are conceiving of the instantiation of instances of new colours.

Does conceivability entail possibility? That is a question that has vexed philosophers for a long time. It seems reasonable to think that it does not—at least in a straightforward sense. This is because there are apparent counterexamples in which something at least seemed to be conceived of by some people, say some mathematical theorem, which then was proved to be false, and hence impossible. However, a good number of philosophers think that at least some forms of ideal, rational conceivability entail some forms of possibility. Some think that it entails logical and conceptual possibility, and others that it also entails metaphysical possibility. To my knowledge, no one, for good reason, thinks that it entails a nomological possibility. (Something is nomologically possible if it is possible given that the actual laws of nature hold, and something is metaphysically possible if it is possible under some set of laws of nature. Something is logically possible if it does not entail a contradiction, and something is conceptually possible if it, together with conceptual truths (such as vixens are female foxes), does not entail a contradiction.) Discussion of these highly complex debates would take me too far from my aims in this chapter, and I refer the interested reader to Chalmers (2002) and Ichikawa and Jarvis (2012) for extended discussions of these topics.

The view that novel colours are possible stands in stark contrast to the position commonly attributed to Wittgenstein that they are not possible—not even logically or conceptually possible. In a variety of writings, Wittgenstein discussed the questions of whether there could be colours other than the ones we see and whether the concept of such colours even makes sense. He is particularly vexed by the question of how we would know that a newly experienced property was a colour. He also discusses whether specific alleged novel colours like reddish-green could be perceived or experienced, or whether the idea of such colours is coherent. Lugg (2010) makes a careful summary of Wittgenstein's remarks and suggests that while the popular interpretation of Wittgenstein has been that at least at some points in his career he claimed that there could be no perceptual experiences of reddish-green, instead, Wittgenstein "is genuinely puzzled, [and] … he is pulled in both directions and cannot commit himself either way" (Lugg, 2010: 172). Nonetheless, inspired by reading some of Wittgenstein's remarks, some philosophers, for example Brenner (1987), have held that there simply could be no experiences as of a reddish-green on conceptual grounds.

I have little sympathy for this type of view. The justification that is sometimes given for it is that our language, as we know it at present, excludes there being other colours. But I don't find this claim at all plausible. The fiction writers, some of who were discussed above, who use our language to talk about novel colours demonstrate that this claim is false. Moreover, while there could be some instances in which we might worry whether an alleged novel colour was a colour, it would seem that there could be clear cases where that worry could be easily assuaged. For example, if the alleged novel colour was a uniform quality that seemed to adhere to the surface of an object in place of any of the non-novel colours, and if it bore some similarity to the non-novel colours in core ways, such as phenomenally looking to contain red and/or green, or light/dark, or various levels of saturation, then there would be no doubt in my mind that we should classify it as a colour. For example, some of the candidates for being non-novel colours are shades of non-novel colours, such as the shade of red that one might speculate that one could see if one's visual system could respond to more of the electromagnetic spectrum than that which humans can, namely the infra-red. It is tempting to think that the classic colour space could be extended to include such a novel infrared colour by a continuous series of shades of colour leading away from red towards the novel infrared colour. Likewise, as we have seen, another candidate novel colour is reddish-green. Recall that opponent process theory predicts that we could not see or experience such a shade as signalling of red is at the expense of green and vice versa. However, if this turns out to be false, then a reddish-green colour would share certain features of the non-novel colours. For example, the classic colour space could be extended to include a new continuous series of shades of colour from red to green that doesn't go via grey or yellow or blue, that would capture that reddish-green colour, by increasing the dimensions of the colour space.[17] Being able to extend the colour space in a continuous fashion to include alleged novel colours would show that they shared important features with non-novel colours, for example having some saturation and lightness and similarity in hue, that I believe would warrant the judgement that they are colours. (It is interesting to note that this methodology of extending the range of visible colours by postulating an extension to their series in a continuous fashion is precisely how MacDonald introduces his Fairyland novel colours in the quote above.)

Before closing I would like to note that Nida-Rümelin and Suarez (2009) offer an interesting argument that while there can be novel colours there are limits on what possible types of novel colours there can be. For example, they claim that there could not be a shade of violet that did not look to contain both red and blue—and they argue that we can know this based on what we can conceive and imagine. Whether this is indeed the case, I leave to the reader to decide.

Finally, the holder of the view that novel colours are logically or conceptually impossible has to wrestle with the empirical evidence that has been adduced that there actually are such colours or experiences of such colours. I will come back to examine that evidence in later sections of this chapter.

3.2 Colour blindness

There are a variety of different forms of colour blindness and impairment in humans. In simplistic terms, and looking only at extreme forms of colour blindness rather than more mild impairments, there is red-green colour blindness and blue-yellow colour blindness, which affect the red-green opponent channel and the blue-yellow opponent channel respectively. This is caused by a lack of one of the three cone types: short, medium, or long wavelength, and so people with this form of colour blindness are called dichromats, as opposed to people who are not colour-blind who are called trichromats. There is also achromatopsia, a condition in which people (called monochromats) have, in effect, only a light/dark opponent channel and so are insensitive to chromatic colours. It is testament to the strength of the colour space that it predicts these patterns of colour blindness that we discover in the world.

The traditional view of the nature of colour blindness is that people who have it experience a subset of the colours that those with standard vision who lack colour blindness see. I will call this the 'traditional subset view'. Which colours those are will vary depending on the type of colour blindness. It was often thought, for example, that people with red-green colour blindness simply failed to experience reds and greens and just had chromatic experiences of yellow and blue. So the colour space of a red-green colour-blind person would consist of a two-dimensional area formed by a white and black axis and a blue and yellow axis, entailing that the person would be able to see blues and yellows of different lightness and brightness and saturation, in addition to white, black, and various greys (and note that thereby they would be curtailed so that they see only unique shades of blue and yellow).[18] We now know that this is likely to be a too simplistic account of what colours the colour-blind can experience. So what alternatives are there to the traditional subset view?

One important source of evidence about what colour-blind people see comes from those who are colour-blind in one eye and not the other. Evidence from this source has typically been taken to support the traditional subset view. However, Broakes (2010) shows that far from settling the matter, these reports raise more questions. For a start, these reports are, actually, highly variable. They range, in the case of red-green colour blindness, from reports of just blue and yellow chromatic colours, to reports of blue and yellow and in addition reds or greens or both, at least to some degree. (Broakes, helpfully, goes to great length to explain how it might be possible for red-green colour-blind people to have experiences of reds and greens.). Nonetheless, this evidence still points towards the idea that colour-blind people experience—to a greater or lesser degree—a subset of the colours that those without colour blindness experience.

In contrast to the subset view of colour blindness, a new account of colour blindness has arisen recently in the philosophical literature. According to this new theory, people with colour blindness see and experience none of the colours that those with normal colour vision experience.[19] Consider a red-green colour-blind person. The new account would say that not only does that person not see red or green, they don't see yellow or blue either. Instead, they see some other colours entirely—some less determinate colours. Byrne and Hilbert (2010) discuss this view, and call these other colours "alien". As I explained in section one, I think that there is good reason to avoid this name and so I will stick with calling these 'novel' colours.

In order to motivate the new theory of colour blindness, Byrne and Hilbert explicate a major problem with the standard view of colour blindness. They claim that, according to the standard view, a colour-blind person will see almost every colour incorrectly (supposing that physical objects do have the colours that we normally take them to have). To explain why, let's take red-green colour blindness again as an example. On the standard view people who are red-green colour-blind are limited to only seeing shades of unique blue and unique yellow (more or less saturated shades and more or less light shades) because they lack one of the cone types that feed into the red-green channel. Byrne and Hilbert speculate that these people therefore lack the red-green opponent process. If that is right, then any object that does not have either of the precise unique hues of blue or yellow (so nearly every object) will be misperceived—unless we can argue that objects can have multiple colours at the same time. This is a highly unwelcome consequence of the standard view. Moreover, the same would be true of a great deal of the animal kingdom, for many animals are dichromats. And, in addition, we know that dichromatic colour vision evolved before trichromatic vision, so we would have to say either that before trichromatic vision evolved, colour perception was mostly inaccurate—or that objects can have multiple different colours at the same time. These seem very hard bullets to bite.[20]

On the alternative view, we should think of colour-blind people as simply detecting different colour properties from any of those colour properties that those who are not colour-blind detect. And, given Byrne and Hilbert's specification of those colours, the colour-blind will turn out to be right a good deal of the time about those colour properties that they do detect, which would make this view exceptionally attractive.

Byrne and Hilbert's particular version of this view is that if you lack a red-green opponent channel, then any signalling of what we would otherwise think of as yellow or blue by the blue-yellow opponent channel does not actually amount to the signalling of yellow or blue. Consider that when a person with normal colour vision has their blue-yellow opponent channel signal for what we would normally think of as yellow, then that signal alone does not determine the overall signalling of colour. There will be a contribution by the red-green opponent channel too. It will either be signalling for what we typically think of as red or green to some degree or, be neutral with respect to those (in this latter case, it signals a balance of red and green, by staying silent and failing to send a signal about red or green). So, in a person with normal colour vision, what needs to occur for unique yellow to be signalled for is both the blue-yellow opponent channel to be signalling for what we normally think of as yellow and for the red-green opponent channel to signal for neither of what we normally think of as red or green.

Now, Byrne and Hilbert argue that there is good reason to think that many dichromats will simply lack a red-green channel, particularly congenital dichromats (2010: 282). Let us suppose that this is true (although it certainly could be questioned, and no physiological evidence backs up their specific claim here). In that case, argue Byrne and Hilbert, the signalling in a red-green colour-blind person of what we normally think of as yellow by their blue-yellow opponent channel does not amount to a signalling that yellow is present. Because for that to happen the red-green opponent process must signal a balance of red and green (by neither signalling red nor green). But they lack such an opponent process. Therefore, the idea is that nothing is signalling that red and green are in balance in a red-green colour-blind person—even though this is signalled in someone who has red-green channels by a failure to signal either red or green. In short, the lack of signalling for red or green in someone who has red-green opponent processes is not the same as the lack of signalling for red or green in someone who lacks red-green opponent processes. So, what gets signalled for in a red-green colour-blind person when their yellow-blue channel fires is that something *yellowish* is present, namely, that something that lies in the half of the hue circle between (but excluding) unique red and unique green going through lime green and yellow and orange is present. And, likewise, in the case of signalling what we normally think of as blue, what is really being signalled is that something *bluish* is present: something that lies in the half of the hue circle between (but excluding) unique red and unique green going through turquoise and blue and purple is present. And Byrne and Hilbert claim that the property of yellowish is a determinable of which unique yellow, oranges, and lime greens are determinates. And bluish is a determinable of which unique blue, turquoise, and purple are determinates. Thus, their idea is that red-green colour-blind people see colours that are less determinate than people who are not colour-blind. The people who are not colour-blind see colours that are more determinate than the colours that red-green colour-blind people see. So, in fact, red-green colour-blind people see none of the same colours as those who are not colour-blind see.

Finally, Byrne and Hilbert argue that the evidence from people who are colour-blind in one eye who testify to seeing either blue or yellow (and as we saw, sometimes red and green) can be set aside, for these are special people who due to their non-colour-blind eye will have red-green opponent channels in their cortex, which receives signals from both eyes, that will be signalling either for red or green or neither, even when they are seeing using only their colour-blind eye. This allows them to neatly side-step the empirical evidence that would otherwise prove problematic for their view.

Byrne and Hilbert's view is ingenious and has a lot to recommend it. If it is right, we would have identified some novel colours of a particular form: colours that are determinables of the determinates that those with normal colour vision see.[21] And, moreover, as I will discuss in the next section, as it is likely that there are people and animals who have more sensitive forms of colour vision than statistically normal humans, we will be able to identify other novel colours. If Byrne and Hilbert's view can rightly be applied to them then people and animals who have more sensitive forms of colour vision than humans with normal colour vision will have experiences of more determinate colours than those of statistically normal humans. And to reiterate, on this view, the vision of all of these different sorts of colour perceivers can be correct about the colours that are represented to be present, for what is different is simply how determinately the colours present are represented to be. (It should be noted that colour perceivers could also be correct about the colours that they represent to be present on a surface, even if they represent different colours, and not simply different as to how determinately the colours present are represented to be, contra Byrne and Hilbert and in line with the traditional theory of colour blindness articulated above, so long as we allow that objects can simultaneously have two distinct colours. (See footnote 20.)

As I said previously, Byrne and Hilbert's view depends on holding that dichromats lack a second opponent channel and that a colour experience as determinate as those that people with normal human trichromatic vision have cannot occur with only one active channel, and while Byrne and Hilbert offer plausible reasons for their view, they are not conclusive. However, when we turn to thinking about human tetrachromats, as I will do in the next section, we will find conclusive reasons for thinking that there are novel colours, as it is overwhelmingly plausible that human tetrachromats see colours in addition to those that people with normal trichromatic colour vision do. So, a more secure source of novel colours can be found. In addition, we will see that just as there were two accounts of the nature of dichromatic vision in comparison to trichromatic vision, there are two parallel accounts of the nature of tetrachromatic vision. Thus, both the standard account of dichromacy and Byrne and Hilbert's alternative view will be hugely useful in thinking about the nature of the relationship between trichromatic and tetrachromatic colour vision.

3.3 Tetrachromacy

As previously discussed, standard human colour vision involves three cone types that detect short, medium, and long wavelengths. And these signals are combined to yield three opponent channels: an achromatic light/dark one, and two chromatic ones, a red-green one and a blue-yellow one. And we have just been looking in detail at forms of dichromacy—they involve having only two cone types and hence, we speculated, only one achromatic and one chromatic opponent channel.

In the animal kingdom, and surprisingly in humans too, we also find tetrachromacy: colour vision that operates via four cone types. Birds, reptiles, and several freshwater fish have four colour receptors.[22] (Indeed, in the animal kingdom we find creatures—mantis shrimp and butterflies—that possess up to 12 spectral sensitivities in their eyes. Mantis shrimp have 20 receptor types in total: 12 for colour, 6 for polarization, and 2 with overlapping function for luminance tasks.) Marshall and Arikawa (2014: R1150) state that three factors determine the nature of a creature's colour vision: "the number, shape and chromatic spacing of the spectral sensitivities; second, behind the retina, how interneuronal channels encode a chromatic message to the brain; and third, the behaviour of the animal relative to spectra (light and reflectance) in its environment". We should add to that the nature of the colour processing that takes place in the brain. Some animals have different types of receptors in different parts of their eyes, as opposed to those receptors being spread out evenly throughout their eyes. Some combine information from all of their different receptors, some pool information from some of their receptors in groups, others do not. The richly different forms of colour vision to be found in the animal kingdom are extremely likely sources of novel colour experiences of one sort or another—the reason being that these different visual systems will give rise to sensitivity to, and behavioural response to, lightwaves reflecting from surfaces that is vastly different from that of humans with normal vision—and indeed that of any human.

Exactly how information is pooled from different receptors in animals is the area in which human knowledge is most limited in animal colour vision science. For this reason, and for the reason that we can get the best behavioural data and verbal reports from humans, I will now limit my discussion to human tetrachromacy. But, as we will see, that case illustrates the point that many different visual systems in the animal kingdom also make.

Due to the genetics of colour vision, mothers or daughters of males who are anomalous trichromats—meaning that either their medium wave receptor is replaced with one closer to their long wave receptor or vice versa—turn out to have a shortwave, a medium wave, and a long wave receptor, and an additional receptor either close to the medium wave or long wave receptor. While there has been reason to believe that there were such women for a long time, it was not known whether those women's brains exploited the extra information from the extra receptor—and hence were tetrachromats. In other words, as is the case with our present knowledge of animals, it was not known how the interneuronal channels encoded chromatic messages to the brain. However, in a recent study by Jordan *et al.* (2010) 24 such women were studied. Of these women, 23 did not exhibit behaviour that suggested that they were tetrachromats, but 1 did.

The subject, known as 'cDa29', passed a number of tests that indicated that she was a tetrachromat. The most important test was the Rayleigh match test—a test in which subjects are asked whether they can discriminate—pick out—one light that is different from two others. On each trial, two of the three lights were a monochromatic orange light and the third was of a mixture of a red and a green light. The task was to identify the odd one out. Humans with normal vision—trichromacy—can't do this. But this one subject could do so—and could do so quickly, and with that same speed given different versions of the stimulus. The authors of the study conclude that they have found "one person, a carrier of deuteranomaly, who satisfies the criteria for behavioural tetrachromacy on all our tests" (2010: 15).

What this study tells us is that if a human with normal colour vision and the human tetrachromat identified in the study looked at certain patches of colour, they would look the same to the human with normal vision, but they would look different to the tetrachromat. In fact, there is a whole extra dimension of colour experience that the tetrachromat has that humans with normal trichromatic colour vision lack. In this respect, the relationship between humans with normal trichromatic colour vision and this tetrachromatic woman are like the relationship between a dichromatic red-green colour-blind person and a normal trichromatic human. In the last section, we saw that there were two options for how to conceive of this relationship. First, we could think that the dichromat sees a subset of the colours that the trichromat sees. Likewise, we could think that trichromats see a subset of the colours that the tetrachromat sees.

A downside of this view is that we have to say that (at least) two out of these three types of perceivers—dichromats, trichromats, or tetrachromats—see most colours incorrectly. Or, second, we could think, with Byrne and Hilbert, that the dichromat, the trichromat, and the tetrachromat see different colours from each other—different in that they see different determinates and determinables of the same shades of colour. And a virtue of this view is that, as these colours are not incompatible, we need not say either that any of the three types of perceivers mostly perceive colours incorrectly.

Whichever of these views we adopt, each entails that tetrachromats see colours that normal human trichromats do not. Thus, there are novel colours: experiences of hues of colour in addition to those that the standard colour theory says that humans (with what is defined to be "normal" tri-chromatic vision) have in standard viewing conditions.

An alternative view would be that tetrachromats see qualities other than colour qualities when they look at a surface. One version of this view would be that they don't see colours at all—that they see novel non-colour properties. As discussed in section 3.1, I find this view highly implausible. If the alleged novel properties were uniform qualities that seemed to adhere to the surface of an object, if they could be lighter and darker, more or less saturated, then there would be no doubt in my mind that we should classify it as a colour. To back up this view it would be good to gather detailed phenomenal descriptions of the qualities that human tetrachromats describe, and their relation to what human trichromats describe the colours as having. A second version of this view would be that human tetrachromats see the colour qualities that trichromatic humans see but that the tetrachromats see extra non-colour properties in addition to those. This is something that could be empirically tested in part—we would have to ensure that the phenomenal descriptions of the colour experiences of the tetrachromats bore out this interpretation. However, the question would again rise, why these extra properties should not be taken to be colour qualities. I have already articulated my view on this matter, so I shall not continue discussion of this matter further.

I turn now to discuss the evidence for novel colours by looking at evidence about chimerical colours.

3.4 Chimerical colours

As we have seen, the standard colour space, underpinned by the opponent process theory, outlined in section two, is said to have explanatory power regarding colour blindness. It is also said to have explanatory power with respect to after-images. This will be the major topic of investigation of this section, for it is claimed that there are a variety of novel colours, called 'chimerical' colours, that are induced by projecting after-images onto coloured surfaces.

To begin, I will explicate what proponents of the standard colour space say about after-images in general, before looking at the specific form of after-images that are said to produce chimerical colours. I will then examine objections both to the standard account of after-images and to chimerical colours in particular.

It is frequently reported, by numerous philosophers and psychologists, following Hurvich and Jameson (1957), that fixation of tens of seconds on a patch of red gives rises to an after-image of green when one subsequently looks at a white or grey surface, and vice versa.[23] And, similarly, fixation on blue gives rise to a yellow after-image, and vice versa, and similarly for black and white. I will take these claims for granted at the moment, but I will return to question them later in this section.

The explanation of this, derived from the standard colour space and the opponent process theory that lies behind it, is that as you fixate on a colour, say red, the opponent cells fatigue in their ability to signal for red, so that when you look at a neutral white or grey surface that contains neither red or green, rather than signalling for both a lack of red and green, the opponent cells signal the presence of green. Thus, you see a green after-image. The three opponent processes, red-green, blue-yellow, and white-black, therefore, apparently account for why we experience after-images, and why we experience the particular colours that we do subsequent to looking at differently coloured stimuli.

Elaborating on another suggestion in Hurvich and Jameson (1957), Johnston (2004) and Churchland (2005) used the opponent process theory to predict that certain colours that do not appear in the standard colour space should be experienced (by those with normal trichromatic vision) when certain after-images are projected onto certain coloured back grounds. These are colours that don't have instances in the physical world, for no combination of wavelengths stimulating the eye alone could produce experiences of these colours. They can only be experienced by stimulating the eye with certain wavelengths and, in addition, doing so when the opponent processes have been fatigued in the right sort of way.

Recall the idealization of the classic colour space, as illustrated in Figure 11.3. The space, it is claimed, depicts the colours that are instantiated in the world. The idea is that you couldn't have a colour that was lighter than white, for to travel up the vertical axis to the maximum, you reach white and leave behind the chromatic hues, all of which have less lightness than white. Similarly, you couldn't have a colour that is darker than black, for to travel down the vertical axis as far as one can go, one leaves behind the chromatic hues, all of which have more lightness than black. And finally, one cannot travel out beyond the most saturated versions of each colour: red, green, orange, purple, and so on, that can be caused by light entering the eye.

But recall that these explanations, based on the colour space, are based on a model constructed by noting the colours that people report when stimulated by the various different combinations of wavelengths, in typical viewing conditions. Can we create further colour experiences in people by dispensing with typical viewing conditions? Hurvich and Jameson (1957), Johnston (2004), and Churchland (2005) claim that we can. Between them, they claim that there are three new types of colour experience that can be had in the following ways:

1 **Stygian colours** look maximally dark, as dark as black, yet they have a chromaticity. It is claimed that one such colour can be seen by fixating on a patch of yellow, and then projecting the subsequent blue after-image onto a black surface, or, equally, by fixating on a patch of white, and then projecting the subsequent black after-image onto a patch of blue. What is experienced is said to be "fully as dark as the darkest possible black … but nevertheless is of an obvious and distinctive [blue] hue" (Churchland, 2005: 544). He goes on to say (2005: 545), this is "a color that you will absolutely never encounter as an objective feature of a real physical object, but whose qualitative character you can nonetheless savor in an unusually produced illusory experience".

2 **Self-luminous colours** look maximally light, thus as light as white, yet they have a chromaticity. For example, if you fixate a patch of red and project the subsequently experienced green after-image onto a white surface you will see that "the bright green(ish) after-image seems positively self-luminous, as if it were a colored light bulb or a colored LED (light emitting diode)" (Churchland, 2005: 547). Such a colour experience can be had veridically, for example, by looking at a coloured LED. But the standard colour space predicts that when looking at a non-self-luminous surface, as one in in the specified condition, this colour cannot be seen.

3 **Hyperbolic colours** look to be supersaturated—more saturated than the maximal saturation that standard colour space would anticipate is possible. They are said to be experienced when, after fixating on a maximally saturated chromatic patch, say a shade of blue-green, one then projects the subsequent orange after-image onto a maximally saturated orange patch. Churchland (2005: 553) claims that one then experiences, "an orange that is more 'ostentatiously orange' than any (non-self-luminous) orange you have ever seen, or ever will see, as the objective color of a physical object". While Churchland thinks that only binary colours can be experienced as supersaturated, Johnston (2004: 141), following Hurvich and Jameson (1957), claims that unitary colours can be too. He says that if one projects one's red after-image onto a red surface after "being exposed to bright monochromatic unique green light (500 nanometers in wavelength) in an otherwise dark room for about twenty minutes", then one will experience supersaturated red.

If there are experiences of chimerical colours—at least stygerian and hyperbolic chimerical colours—then there are experiences of novel colours. (The case of self-luminous colours is a tricky one, and I will leave the reader to decide whether it should count as being a case of a novel or not.) But are there such experiences? Some doubts about them have recently been raised in the literature.

One doubt is whether the opponent process theory underlying the standard colour space, can account even for simple non-chimerical after-images that are projected onto white or grey surfaces. There are two sources of worry. One is physiological, the other is phenomenological.

Jameson and D'Andrade (1997) summarize the mounting physiological evidence that while opponent processes have been found in the cortex and LGN (lateral geniculate nucleus) of primates, the opponency does not correspond to the red-green and the blue-yellow axes.

With regards to phenomenology, there is a major problem: after-images don't seem to follow the patterns predicted by the opponent process theory. A red stimulus does not produce a green after-image but a blue-green (cyan) one. A green stimulus produces not a red after-image but a blue-red (magenta) one. Lest one think that this is a new observation, Jameson and D'Andrade (1997: 307) also point out, "As early as 1907 Hering's student, A. von Tschermak, reported that, 'under usual conditions of observation, in order to produce a colorless appearing mixture (of lights) one needs for a unique (urfarben) red not a pure green but a somewhat bluish-green' (Tschermak 1907: 478)." And this observation has been subsequently and repeatedly made since.[24]

It is notable that this counter evidence to the opponent process theory has mostly been ignored in textbook and research papers on this subject, as Jameson and D'Andrade (1997) and Pridmore (2011) explicitly remark. Nor has it reduced the use of the opponent process model in cognitive psychology research. One reason might come from the observation by Pridmore (2011) that when researchers found colour opponent cells in fish and primates that amounted to red-cyan opponent processes, they kept calling them 'red-green', nonetheless. Researchers seemed to be so pleased to find opponent processes, at a time when the theory was not universally accepted, that the fact that the antagonists were a little bit different (blue-green, rather than green)) from what was predicted seemed a minor point.

The latest research into this matter suggests that after-images obey rules corresponding to complementary colours, rather than the traditional opponent colours. Complementary colours are those that when mixed in suitable proportions yield a colour match to some achromatic stimulus (black, white, or shade of grey).[25] Thus, different opponent processes are needed to account for the after-images that humans perceive. Pauli (2010) argues that red-cyan, orange-blue, yellow-violet, and green-magenta opponent processes are required, in addition in a white-black one. Pridmore (2011) argues that red-cyan, blue-yellow, and green-magenta opponent processes are required, in addition to a white-black one. Just as Hurvich and Jameson (1957) combined the tri-chromatic and opponent process theories arguing that at an earlier stage of processing there are trichromatic processes and at a later stage opponent processes, so Pridmore combines that idea with his results about complementary colours. He holds that the levels and types of processing that Hurvich and Jameson posited exist, and account for many facts about the colours, but he posits a third stage of processing that involves complementary opponent processes, which take place after the first two posited by Hurvich and Jameson.

If the opponent theory is incorrect with respect to the colour of simple after-images projected onto white or grey surfaces, as the recent scientific work on the topic indicates, what, if anything, does this tell us about chimerical colours that were posited as an extension of opponent process theory? Does the science affect the reasons to think that there are chimerical colours?

Manzotti (2017) goes to great lengths noting and recording all those who explain after-images in terms of the traditional opponent theory and points out that it does not accord with phenomenological observations about which after-image colours are experienced in different situations, as I described above. He too holds that after-images work according to complementary colour rules. And he tries to press these facts into service of his theory of perception, according to which, instances of what are traditionally called illusions and hallucinations, are really instances of seeing something, and seeing something accurately, in the world. In the case of illusion, we are seeing something here and now; in the case of hallucination we are seeing something that we have seen in the past. Manzotti treats after-images as if they were veridical perceptions. He claims that when I see a cyan after-image in response to fixating on a red figure and then looking at a white surface, the fatiguing of the cells that signal for red mean that I no longer perceive the redness of the white surface. I now see the component other than red that is left within the white: cyan. This argument supposes that a white surface either always, or—what seems to be Manzotti's preferred account—sometimes (when it is viewed in the right way), has the property of being cyan and being red, and has other colour properties when viewed in other ways. This is a highly controversial premise and one that will be resisted by many. That white objects reflect wavelengths, which if reflected alone from a surface would lead us to say that the surface had a (non-white) colour corresponding to those wavelengths, does not entail that a white surface always or sometimes has those colours too. Standardly, surfaces are thought to have just one colour at a time, and don't change their colour depending on what perception is occurring of them. White surfaces are white, not (perhaps also) cyan when one's red receptors are fatigued.

This strategy of accounting for after-images as veridical perceptions does not fare well on two other accounts. First, one case of simple after-images seems to provide a counter example to Manzotti's account. If one fixates on a black stimulus then one will have a white after-image if one projects the subsequent after-image onto a black surface. If we apply Manzotti's account of after-images to this case then the explanation of what is occurring that we should give is that one is failing to see some of the black surface's aspects—by a filtering or subtracting process caused by the lesser sensitivity of the visual system to white—revealing the black surface's white aspect. But that can't be right. There is no white aspect in the black surface that a lack of sensitivity to some elements of the black surface would reveal. A black surface is black because it absorbs wavelengths of light, unlike white which reflects them. If we become less sensitive to wavelengths of light due to fatigue then we should not be more sensitive to white. Thus, this case presents a serious problem to Manzotti's account of after-images.

Second, if there are chimerical after-image colours, these too would pose a problem for Manzotti. This is because they are not colours that are somehow contained in surfaces and that can be revealed by subtraction. Supersaturated red, for example, is not an element of an ordinary red surface and not one that can be seen by subtraction.

Manzotti has a reply to this second problem case. He denies the existence of supersaturated red. He does so by falling back on the observation that red is not the colour of the after-image one experiences after fixating on green and then looking at a white or grey surface. It is magenta, according to the complementary colours theory. Thus, if one tries to do what the traditional opponent theorists have said will produce hyperbolic colours, such as supersaturated red, by fixating on green and then projecting the subsequent after-image onto a red surface, this will not produce an experience of supersaturated red, but an experience of magenta on a red background. "Supersaturated red is a perceptual myth" quoth Manzotti (2017: 171).

However, this argument is too quick. That magenta, and not red, is the colour of the after-image obtained by a green stimulus means only that one cannot experience supersaturated red by projecting a magenta after-image onto a red surface. But what if one produced a red after-image by fixating on a cyan stimulus, and then projected that red after-image onto a red surface? Would one then not experience supersaturated red? Or what if one produced a magenta after-image by fixating on a cyan stimulus, and then projected that magenta after-image onto a magenta surface? Would one not experience a supersaturated magenta? Nothing Manzotti has said would show that these methods would not produce supersaturated hyperbolic colours. Thus, as he has not ruled out the existence of chimerical colours, his theory is still under threat.

Nonetheless, it is clear that in light of the confusion about the colours of after-images, further empirical work is required to establish more conclusively the existence of chimerical colours.

3.5 Synaesthesia

Synaesthesia is a condition in which people report idiosyncratic sensory or other experiential pairings. For example, they might report that whenever they experience a taste they feel a shape, or whenever they hear sounds, they see certain shapes.[26] Following Macpherson (2007), synaesthesia is a condition in which either:

> (i) an experience in one sensory modality, or
> (ii) an experience not in a sensory modality, such as an experience of emotion, or
> (iii) an imagining or thought of what is so experienced, or
> (iv) a mental state outlined in either (i)–(iii), together with recognition of what the mental state represents
>
> is either a sufficient automatic cause of, or has a common sufficient automatic cause (lying within the central nervous system of the subject) with, an experience or element of experience that is associated with some sensory modality and is distinct from (i).
>
> This synaesthetic experience or element of experience can be associated with the same or a different sensory modality from that which may be ordinarily associated with the mental state in (i)–(iv).

Several forms of synaesthesia involve experiencing colour in response to some other stimulus. (In these cases, colour is known as the "concurrent", rather than the "inducer".) One inter-modal form is experiencing colours in response to hearing sounds. Another, intra-modal form, grapheme-colour synaesthesia, is triggered by seeing letters or numerals and they are experienced as having a colour, that they typically lack. For example, '5's printed in black ink might look green, and '4's printed in black ink might look orange. Synaesthetic pairings are typically stable across time.

Ramachandran and Hubbard (2001: 26) discuss cases in which synaesthetes report that their "induced colours are somehow 'weird' or 'alien' and don't look quite the same as normal 'real world' colours". In some cases, these are colour-blind subjects, in which it is surmised that they are experiencing colours that people who are not colour-blind experience, but which they typically don't experience due to their colour blindness. Ramachandran and Hubbard suggest that the synaesthetic colours by-pass the limitations of the colour-blind retinal system to activate the cortex directly, causing experiences of colours not usually seen. In other cases, they are people with normal trichromatic colour vision. In those cases, Ramachandran and Hubbard suppose that unusual activation of the cortex may occur due to its stimulation by an other sensory modality, rather than by stimulation of the retina.

As we will see in section 3.6, this is a very similar explanation to that given by Crane and Piantanida for the experience of novel colours caused by filling-in. I will therefore abstain from further discussion of this type of novel colour and subsume it under the following section, 3.6. I end this section simply by noting that further work on this topic, eliciting as detailed as possible phenomenological reports of these synaesthetically induced novel colours, would be very helpful for those considering the nature of these experiences.

3.6 *Filling-in*

I turn now to examine evidence for the final type of novel colours: reddish-green and bluish-yellow novel colours. It has been claimed by some psychologists that experiences of these colours have been produced in the lab by exploiting the 'filling-in' phenomenon.[27]

Normally the colours we see objects as having depends to a large extent on the wavelengths of light emitted from those objects. In some situations, however, the colour perceived does not in any way so correspond. It has been noted by many psychologists that an image that is stabilized on the retina fades from view, and the brain then 'fills in' the faded region—that is, produces in the subject an experience of that area—in a manner determined by the surrounding unstabilized area.[28] The psychologist Krauskopf (1963), for example, stabilized a green disk on subjects' retinas. This disk was surrounded by an unstabilized orange area. At first the subjects reported seeing a green disk on an orange background, but within several seconds reported that the green disk faded from view to be replaced by a uniformly orange surface. When retinal cells receive no change in the information that they detect, they cease to respond. The device used to stabilize an image on the retina is called an 'eye-tracker'. It is important to note that what gets 'filled-in' depends on the area surrounding the stabilized area. A similar, but not quite so prominent, effect can be seen by fixating one's eyes in the centre of a green disk on an expansive, uniform orange background. After a time, the green disk fades from view and is 'filled-in' with orange. This is the Troxler effect.[29]

Exploiting the filling-in phenomenon, Crane and Piantanida (1983) presented subjects with a red vertical stripe abutted to a green vertical stripe. The top and bottom of the stripes extended beyond the subjects' field of view. The outer edge of each stripe was formed by a black occluder. Crane and Piantanida stabilized the red-green boundary area using an eye-tracker but they ensured that the black occluders were not stabilized.

The thought behind the experiment was that the area that was to be filled-in was surrounded not by one colour, as in the Krauskopf filling-in experiment, but by two opposing colours, therefore providing conflicting information to the brain, when it tried to fill-in the area corresponding to the stabilized part of the image. Observers of the image reported different things that they saw in the stabilized area, which fell into the following three categories:

1 The entire field was covered in a regular array of very small (just resolvable) red and green dots;
2 The field contained either islands of red on a green background or vice versa;
3 The field contained a novel hue that subjects reported never having seen before.

The experiment was repeated with blue and yellow areas, with corresponding results.

The response that is of interest to us is the third one. Crane and Piantanida describe that response further:

> some observers indicated that although they were aware that what they were viewing was a color (that is, the field was not achromatic), they were unable to name or describe the color. One of these observers was an artist with a large color vocabulary.
> *(1983: 1079)*

Other observers of the novel hues described the novel colour as a reddish-green. Crane and Piantanida's description of the colour is that it appeared to have the characteristics of a binary colour, one phenomenally composed of red and green, in the way that other binary colours seem to be so composed. For example, orange seems to be phenomenally composed of yellow and red, and purple seems phenomenally to be composed of red and blue. The colour was not uniform across the field though, as it was "greener near the unstabilized green boundary and redder near the unstabilized red boundary" (1983: 1079)—just as a field of orange could be a more reddish orange on one side, transitioning smoothly to a more yellow orange on the other.

Such results appear in conflict with the opponent-process model of colour vision, which predicts that one cannot have experiences of reddish-greens because when responding to redness, one is simultaneously responding negatively to green. However, Crane and Piantanida speculate that the opponent-process model applies only in cases where the retina is stimulated by light and not to those cases that involve the filling-in phenomenon, where the retina is not stimulated. They believe that the filling-in phenomenon results from purely cortical activity, unrestrained by lower-level retinal-cortico processes that display opponency. In other words, experiences of colour produced by the filling-in phenomenon are not restricted to opponent channels and thus can appear reddish-green or bluish-yellow.

If Crane and Piantanida's experimental reported results are true then we would have instances of experiences of novel colours—and the most convincing instances out of all of those that I have examined in this chapter. However, Crane and Piantanida's conclusions have been challenged.

Hsieh and Tse (2005) complain that Crane and Piantanida reply solely on subjects' verbal reports of the colour. They argue that Crane and Piantanida cannot rule out the idea that the subjects saw a non-novel colour—a brownish colour in the case of alleged reports of reddish-green, and a yellowish colour in the case of bluish-yellow. Hsieh and Tse carried out an experiment that didn't use an eye-tracker to produce filling in but that relied on Troxler fading during fixation. Cleverly, they got subjects to produce a match to the filled-in colour that was experienced by adjusting another patch of colour that was at the same time in the subjects' field of view. In the case of reddish-green subjects matched a perfectly possible brownish colour; in the case of filling-in in response to a red and green stimulus. Thus, Hsieh and Tse failed to replicate Crane and Piantanida's results and they are sceptical that novel colours were produced in their experiment.

However, Crane and Piantanida's experiment was replicated more faithfully by Billock *et al.* (2001). Unlike Hsieh and Tse, Billock *et al.* used an eye-tracker for stabilization. In the version of the experiment that they conducted, they conducted trials in which they ensured that, for each participant, the shades of red and green chosen were isoluminant for that subject.[30] With this modification, they could reliably elicit reports of novel colours in six out of seven observers—the seventh observer's vision only experienced grey (Billock and Tsu, 2010). Sometimes those who saw the novel colour reported "a gradient of color that ran from, say, red on the left to green on the right with a large region in between that seemed both red and green" (Billock *et al.*, 2001: 2398). At other times they experienced "a homogeneous mixture color whose red and green components were as clear and as compelling as the red and blue components of a purple" (Billock *et al.*, 2001: 2399). In the trials in which non-equiluminant colours were used, they obtained only reports similar to the first two sorts of reports made by Crane and Piantanida: very small (just resolvable) red and green dots or islands of red on a green background or vice versa.

This replication and refinement of Crane and Piantanida's experimental results lends weight to those results, and provides a potential explanation of why Hsieh and Tse didn't replicate the results: they didn't use an eye-tracker or equiluminant stimuli. Yet, one element of Hsieh and Tse's worry remains: Billock *et al.* didn't test to see if subjects could match a possible surface colour to the allegedly impossible one that participants said that they experienced. We would clearly be in a stronger position to claim that there can be experiences of novel colours elicited in the filling-in experimental set-up if evidence could be provided that this cannot not be done. I will return to consider this objection in the next section. Nevertheless, there is fairly substantial and replicated evidence in favour of there being experiences of reddish-green and bluish-yellow novel colours.

In the next section—the final section in which I will look at evidence for the existence of experiences of novel colours—I turn to discuss the cutting-edge, as yet unpublished, work of the aesthetician Michael Newall—with his permission—on the subject of novel colours in paintings.

3.7 Painting

Newall (unpublished) was provoked by a question from a painter: is it possible to paint a continuous fade of yellow colour to blue, without going through green or red (or an achromatic colour) using acrylic paint? Basing an answer on the traditional colour space, we have already seen, would provide a negative answer to the question. However, Newall knew that some people thought that some painters had achieved this effect, and that some people thought that it must be possible, because sometimes they said that they saw the sky as a gradation going from blue to yellow (vertically downwards), without green or red or other hues featuring in what they saw. For example, Rulon Larsen said:

> I know why the sky is blue during the day, and why it turns yellowish to reddish at sunrise and sunset. My question is; why doesn't the sky ever look green? Why does the color go from blue to yellow?
>
> *(on physlink.com)*

And James Elkins in *How to Use Your Eyes*, New York: Routledge, Fig. 26.1, p. 197 (2000), produced a series of images illustrating the colour of the sunset in a clear sky. (See figure 11.4.) Looking east, at half an hour before sunset he describes pale blue fading into pale orange (the shade just beyond yellow), and at ten minutes after sunset he describes a "yellow-blue" shade of colour between blue and orange.

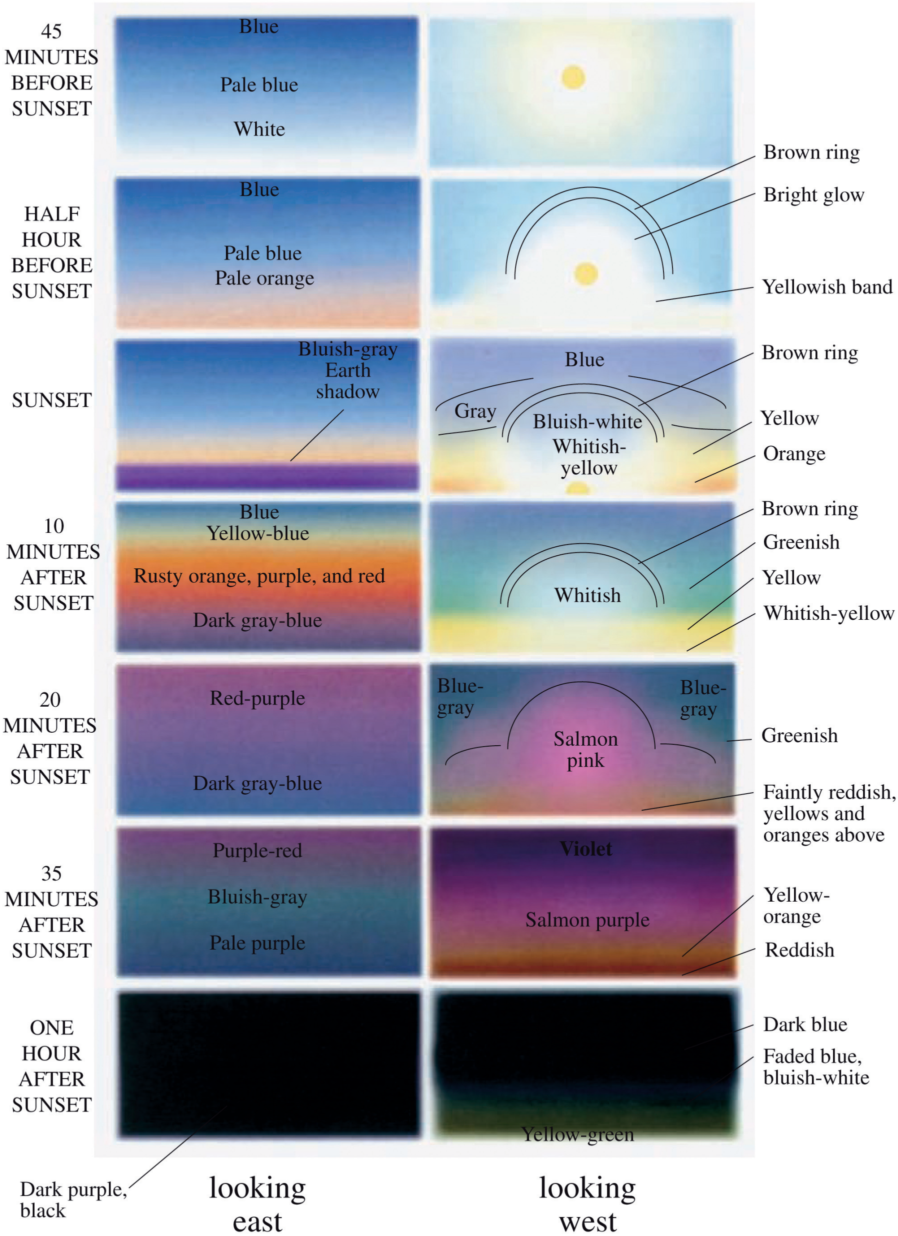


Figure 11.4 From Elkins, J. (2000) *How to Use Your Eyes*, New York: Routledge, Fig. 26.1, p. 197)

Of course, this does not provide conclusive proof that this is how the sky can look, but such detailed observations from colour experts are certainly suggestive.

Newall explains that the effect in question—the fading from blue to yellow directly, without going through other hues of colour—does seem to be achieved in some acrylic paintings.

One can see such a painting being made in the YouTube video by Sean Ryans "How to Paint a Sky—Acrylic Painting Lesson", published 17 August 2013, www.youtube.com/watch?v+ Zr9kMc25bPI, still of which appears in Figure 11.5. In the top two-thirds of the painting there is a gradation from blue to yellow that does not seem to go through any other shade of colour.

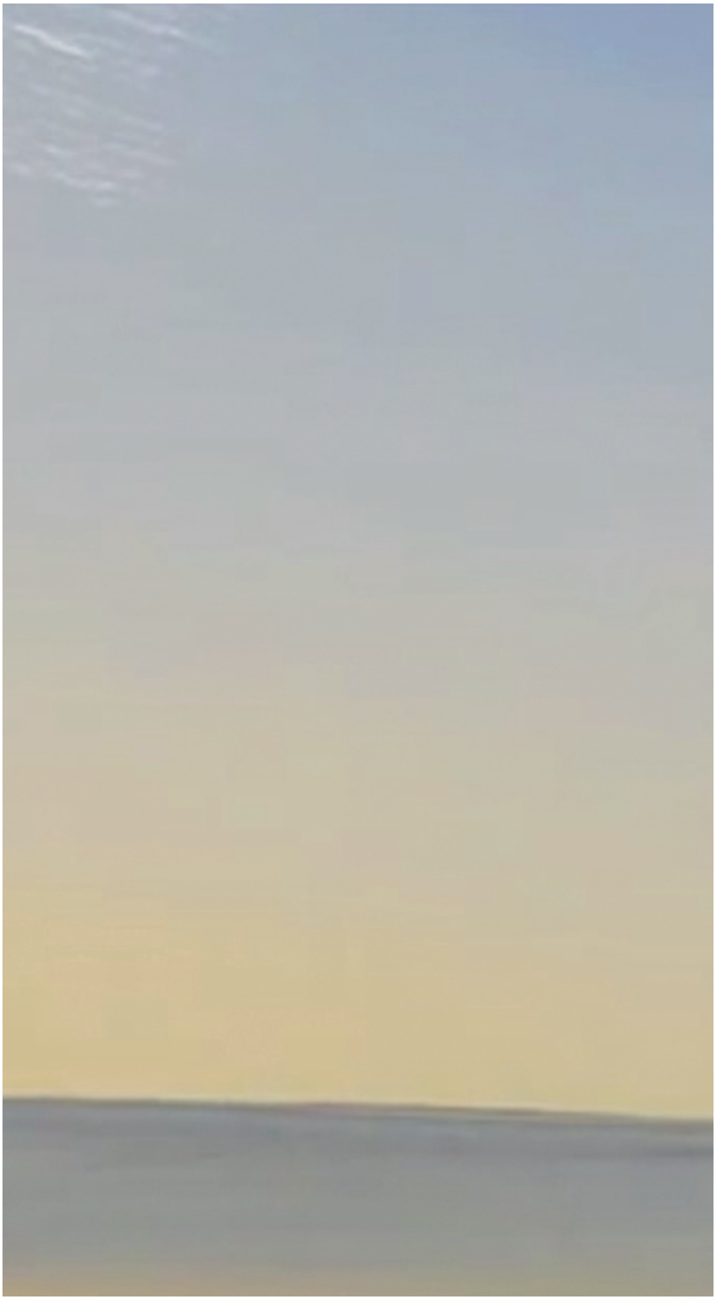


Figure 11.5 A portion of a still from Ryans, S. (2013) "How to Paint a Sky - Acrylic Painting Lesson" YouTube Video, published on Aug 17, 2013, www.youtube.com/watch?v=Zr9kMc25bPI.

Figure 11.6 A portion of a still from Ryans, S. (2013) "How to Paint a Sky - Acrylic Painting Lesson" YouTube Video, published on Aug 17, 2013, www.youtube.com/watch?v=Zr9kMc25bPI.

Newall also cites several well-known paintings in which this effect is achieved, including Claude Lorrain's c.1757 *A Mediterranean port at sunrise with the Embarkation of Saint Paula for Jerusalem*, private ownership, J.M.W. Turner's 1815 *Dido Building Carthage*, The National Gallery, Charles Cuisin's 1815 *Effet de crépuscule, environs de Troyes. La chaussée du Vouldy*, Musée du Louvre, and Charles Gleyre's 1843 *Evening or Lost Illusions*, Musée du Louvre.

Newall asks us to consider in an area of apparent bluish-yellow and how far up the yellowish effect goes, however faintly. And how far down does the bluish effect go, however faintly? He claims that "if those areas overlap, you are experiencing a yellowish bluish colour" (unpublished, slide 20). He notes that the effect can be strengthened by blurring the image by, for example, squinting.

At the same time, Newall notes that "in the area where the blue grades into yellow *the paint itself is a pale grey*—maybe slightly bluish, or slightly yellowish, but never both" (unpublished, slide 27). He says that this can be illustrated by removing a slice from the relevant area of the painting, which is illustrated in Figure 11.6, which is a slice of Figure 11.5.

Thus, Newall concludes that there is no bluish-yellow paint. So, any experience we have of bluish-yellow must be an optical illusion. Newall thinks that a variety of filling-in is taking place. "Where there is a limited stimulus (here a soft, unmodulated, grey with unclear boundaries), the visual system fills it in with information from both the surrounding (yellow and blue) areas" (unpublished, slide 29).

This is an interesting suggestion. The idea is that the bluish-yellow that we experience isn't a colour that physical objects can have or be painted. It is a purely illusory novel colour—the same bluish-yellow that is also claimed to be created by filling-in in the Crane and Piantanida experiments. But the version that we see in the painting is easily available to people (at least those with normal trichromatic vision) to view. It doesn't take an eye-tracker and equiluminant stimuli matched specifically to every subject.

We have here a nice example of neuroaesthetics—an unusual experience predicted and created in the lab by psychologists and neuroscientists—that turns out to have been produced and studied for centuries by artists. I leave it to the reader to assess the merits of Newall's proposal, but for what it is worth, it appears phenomenologically plausible to me.

4 The philosophical significance of experiences of novel colours

Thus far, I have presented a variety of evidence about the existence of experiences of novel colours by looking at an assortment of visual phenomena. I now examine the philosophical significance of experiences of novel colours. While, in previous sections, I have tried to weigh up the evidence in favour and against the existence of these colour experiences, in this section I will simply assume, for the sake of argument, that there are such experiences, and attempt to map out what follows from that claim. This means that most of the claims in this section should be taken to be conditional claims—conditional on experiences of these novel colours existing.

Different kinds of experiences of novel colours have different significance. I start by looking at the conception of experiences of novel colours posited by Byrne and Hilbert in colour blindness. I then go on to discuss the experiences of chimerical colours and reddish-green and bluish-yellow novel colours from the filling-in experiments. It is this latter kind of novel colours that are the most philosophically interesting, so the greater part of this section will be on these.

Recall that Byrne and Hilbert (2010) think that when, say, a red-green colour-blind person looks at a blue object, they will not have an experience that represents it as blue, but "bluish"—because, in order to represent something as blue, the red-green opponent channel must be in balance and hence signalling "neutral" (i.e. neither reddish nor greenish). But red-green colour-blind people lack a red-green opponent channel, therefore they cannot represent that red and green are in balance. 'Bluish' is a technical term, here, the meaning of which is stipulated as being what is represented when the blue-yellow opponent process signals for blue and when there is no signal from a red-green opponent process. Thus, a normal trichromat cannot represent that an object is bluish, in this technical sense, as their red-green opponent process will always be signalling something (even if it signals neither red nor green by signalling a balance between red and green). According to Byrne and Hilbert, neither the red-green colour-blind person nor the normal trichromat are misrepresenting the colour of the object. The object is blue, and the object is bluish.

It therefore follows that, on Byrne and Hilbert's view, the same part of the same object simultaneously has multiple colours—both blue and bluish. And it will have other colours too, given that normal human trichromatic vision will represent something less determinate than a person, or creature, with tetrachromatic vision, who will in turn represent something less determinate than a person, or creature, with pentachromatic vision, and so on.

This view is a variety of pluralism. As outlined in the introductory chapter to this volume by Brown and Macpherson, it is a form of pluralism according to which a ripe banana may be yellow all over, but it is also other colours all over at the same time. Yet it is not an unrestricted pluralism because it doesn't allow that an object can be any two colours all over at the same time. It is restricted to certain determinates and determinables, such a blue and bluish. One might think, therefore, that this view is not too far from a common-sense view. After all, you might think that when a normal trichromat experiences that something is a particular shade of red, say crimson, they also experience that the thing is, less determinately, red, and less determinately still, coloured.

However, the view does depart quite significantly from that common-sense position. In light of the fact that there are tetrachromats and pentachromats, and so on, this means that normal human trichromatic vision will only represent colours that are determinables—determinables of the more determinate colours that those with more colours receptors see. And normal human trichromatic vision won't represent the determinables that the colour-blind represent—determinables of the more determinates that normal human trichromats represent.

A striking concomitant of this view—one that few philosophers have traditionally held—is that in light of the existence of perceivers with more types of receptors, normal trichromatic humans only ever see determinables of some more determinate colour. The view that most philosophers hold is that this is not what our experience is like. It is well represented by David Hume:

> 'tis confest, that no object can appear to the senses; or in other words, that no impression can become present to the mind, without being determin'd in its degrees both of

> quantity and quality. The confusion, in which impressions are sometimes involv'd, proceeds only from their faintness and unsteadiness, not from any capacity in the mind to receive any impression, which in its real existence has no particular degree nor proportion.
>
> *(1740/1978: 1.1.7)*

One philosopher who holds that Hume's view is wrong is Stazicker (2018). In an ingenious paper, he argues, on independent grounds, that we only ever experience determinables and not determinates (and indeed that this is true of every property that we visually experience). It is interesting to note that two separate lines of argument—Byrne and Hilbert's and Stazicker's—both end up concluding that there is only determinable colour experience, a conception that is quite at odds with that of common sense. Greater investigation of this matter would be fruitful territory for further philosophical endeavour.

The novel colours advocated by Byrne and Hilbert on the one hand, differ from the chimerical colours and the reddish-green and bluish-yellow novel colours, on the other, in that only the former are posited to be colours that physical objects can have. Only the former are posited to be perfectly possible, indeed actual, colours of physical objects. I turn now to consider the latter types of novel colours as they present a different set of philosophical ramifications for theories of colour and theories of colour experience.

Chimerical colours and reddish-green and bluish-yellow have in common that they are colours that fall outwith the standard colour space. And they are almost without exception taken to be colours that no physical objects could have because there is no set of wavelengths that a physical object could reflect that would cause a normal perceiver in normal conditions to experience them.[31] This is one reason for thinking that such colours are nomologically impossible. Given the laws of nature, there could not be instances of such colours in the physical world. However, this reasoning supposes that for a colour to be instanced it must be instanced by a physical object, on account of its reflecting certain wavelengths corresponding to the colour. If one doesn't hold that view, then one could think that such colours are perfectly possible, indeed actual. For example, if one thought that colours are distinctly non-physical mental qualia or properties of sense-data (properties of non-physical mental objects), then one could hold that these novel colours are nomologically possible, indeed actual, as they are instantiated in the non-physical mind when people experience them.[32] Or if one thought, as Manzotti (2017: 172) does, that if a perceiver experiences an object to have a colour it thereby makes it the case that that object has that colour then one might think that these novel colours are nomologically possible, indeed actual, as they can be instantiated in physical objects when people experience those objects as having those colours. And if one further thinks, as Manzotti does, that, if multiple perceivers perceive an object to have two different colours on the same part of the same object simultaneously, then that part thereby has both of those colours simultaneously, then this view is a form of unrestricted pluralism.

Going back to consider the view that these novel colours are nomologically impossible, a further question arises whether they are metaphysically possible. The answer to that question will be determined by whether one is an objectivist about colour. As Brown and Macpherson laid out in the introduction to this volume, objectivists think that the nature of colour does not require appeal to perceivers at all. A prominent version of this theory, defended by Byrne and Hilbert (this volume, Chapter 17), draws on contemporary colour science and identifies each colour with a class or disjunction of surface spectral reflectances (SSRs). According to that view, once we have singled out the physical properties that in our world are responsible for colour, those physical properties are the colour properties in all possible worlds. Colour words are taken to refer rigidly to the physical properties so identified, and thus, in all other possible worlds, the judgments of any perceivers are irrelevant to the identity of the colours. Byrne and Hilbert (1997: 282, fn. 8), suggest that the best description of a world with a very different physics from our own is that in such a world objects merely look coloured. Thus, defenders of this type of objectivism will hold that the novel colours under consideration are both nomologically and metaphysically impossible. However, those who are not objectivists and who tie the identity of the colours in a possible world to the judgements of colour perceivers in that world could hold that these novel colours are not nomologically possible, but that they are metaphysically possible. I said "could hold", and not "will hold" in the last sentence, as some such philosophers might hold that these novel colours are nomologically possible too, for a world with our laws of nature might contain very different perceivers who might issue forth the judgements that according to those philosophers determine that some physical objects did have these novel colours.[33]

We can see then that the modal status one takes these novel colours to have is highly dependent on the theory of colour that one holds. This means that theories of colour can be assessed for the treatment that they give of these novel colours—and whether we find it satisfactory. Let me give one example.

One problem that faces those philosophers who think that novel colours are not actual is that they face a particular explanatory burden that the philosophers who think that they are actual do not. The philosophers who think that novel colours are not actual have to come up with an explanation of why having an experience as of those novel colours seems to give people knowledge of what those colours are like. After all, if a colour is not instantiated in virtue of having the experience, then how can having the experience allow people to know what it would be like to see an instance of that colour?

It has long been noted that if one has not perceived a certain thing then, unless one has seen closely related things of the right sort, it is impossible to know what it would be like to see that thing. For example, if one has not seen the colour red, then it is tempting to think that one cannot know, or even visually imagine, what it is like to see red. (Frank Jackson (1986) famously articulated this temptation with his thought experiment about Mary who has never seen red.) What sorts of closely related things would one have to see in order to know what it would be like to see something that one has not? Take the example of having never seen a golden mountain. One could come to know what it is like to see a golden mountain if one has seen a mountain and if one has seen gold, and one can combine these ideas together in the imagination. Another example would be a case in which one has not seen something, say a shade of blue, but one has seen all the other shades of blue laid out in order with a gap in the right place for the shade that one has seen.[34]

An interesting feature of cases in which people have claimed to experience reddish-green and bluish-yellow that is noted in all the papers cited above on the topic, is that after people took part in the experiments that tried to induce those experiences, they said that before having the experience of the novel colours they could not imagine what those colours were like, but after having experienced the colours they could imagine them.

If, in having an experience as of a novel colour, that colour is in no way instantiated—even in the experience or in mental sense-data that one is aware of (if one is aware of any)—then it is mysterious how having such an experience could confer knowledge on one of the nature of the uninstantiated property. If the property is instantiated, and if one comes to be aware of it, then of course that provides a simple explanation of the knowledge that one comes to have. But if the property is not instantiated, and one does not therefore see the property, how can one come to know what it would be like to see the property? Simply stating that one is in a state that represents the property is not a good explanation. Before experiencing reddish-green, I can represent reddish-green by thinking about it and by having beliefs about it. But in virtue of representing it like that I don't come to know what it would be like to see it. One might think that what seems special about visual representation, and that makes it more powerful than representation in thought or belief, is that it makes one visually aware of an instance of the property—but what I am pointing out is that those who endorse this thought need to come up with some reason to believe that this is true in the case of these novel colours if no instances of them exist.

Perhaps the main reason that philosophers have been interested in experiences of these novel colours—the chimerical kind and the reddish-green and bluish-yellow kind—is that they threaten to provide a counterexample to some theories of perception and perceptual experience. Deciding between philosophical theories of perception and perceptual experience is very difficult indeed. One reason is that most philosophical theories of perception are built to accommodate as wide a set of empirical possibilities as possible. That is, to some degree, what makes them philosophical, rather than empirical theories. Thus, it is rare that philosophical theories of perception can be ruled out by discovery of empirical fact. However, I think that some philosophers assumed that there could not be experiences of these sorts of novel colours and so did not build theories that accommodated them. I suspect that many philosophers had ruled out this possibility due to what they found it possible to visually imagine. Let me explain.

Some philosophers seem to use what they cannot visually imagine as a guide to what is impossible. Here is one example, in a case that is not about novel colours. In Macpherson (2015), I point out that Aristotle made the claim that all visual experience must be experience of chromatic or achromatic colour. That is what it is to be a visual experience on his account. That idea has rattled down the centuries with many philosophers repeating the same claim, and citing Aristotle on the matter. But Aristotle gave no reason for the claim. And nor do the philosophers that repeat it. Why? Perhaps they are appealing to Aristotle simply as a wise authority. But I suspect that they also think that a priori reflection on the matter reveals it to be so—it is self-evidently true. And I suspect that many philosophers think that because when they imagine having a visual experience, all they can imagine is experiences that have chromatic or achromatic colour—for they themselves have had no other type of visual experience. However, as I explain in detail in that paper, modern evidence suggests that people can have visual experiences when they are not experiencing colour. I can't imagine what it is like to have such experiences, but I have good reason to believe that such experiences exist and that they are visual, given that they are caused by light entering the eyes and they inform people about the distal environment. In general, it is a mistake to infer from the fact that you can't imagine something to thinking that that thing is impossible.

I think that this sort of faulty reasoning has probably guided philosophers theorizing about perceptual experience. When considering whether there are experiences of hues of colour beyond those that the standard colour space indicates exist, philosophers—like everyone else who has not experienced them—have not been able to imagine any. Thus, I think that they have falsely thought that this is good evidence for believing that there cannot be such experiences. However, as I have shown earlier in this chapter, there is quite strong evidence to think that this is false and that there can be experiences of such novel colours.

Manzotti (2017) provides a different reason for thinking that there are no experiences of these novel colours. He argues that when we examine all the visual experiences that we ever have, perceptual, illusory, or hallucinatory, we cannot find one that isn't composed of solely of elements that we have experienced when seeing the world. We can find evidence of illusions or hallucinations of scenes that we have not seen, but not of scenes that are not composed from elements that we have previously seen. He claims:

> all our experiences—be they a perception or a dream or a hallucination—are made of stuff we encounter in the external world. We do not see or hallucinate colors we have not encountered in the real world. We do not imagine a hue of blue we have never seen. We do not hallucinate or dream of anything that has not been part of the world we have lived in. *We do not experience anything but the physical world in various combinations.*
>
> *(2017: 149)*

By induction, one might argue that there are no such experiences.

So, if, contra these views, there can be experiences of these novel colours, then those experiences have a good chance at helping us test philosophical theories of perception and perceptual experience because they provide examples of experiences that most philosophical theories did not set out to accommodate from the outset, on account of people not believing that their theories had to accommodate such experiences.

Theories that struggle to accommodate experiences of novel colours are ones which explain the phenomenal character of experience in terms that make essential reference to the actual or possible occurrence in the world, of that which one seems to be aware of. I will give two examples of such theories of perception and perceptual experience that are prominent in the current philosophical literature.

The first example is externalist versions of representational theories of phenomenal character. According to representationalism, when we have an experience in which we veridically see the world, that is because we represent the world to be a certain way, the world is that way, and the world is hooked up to the experience in the right way—it is often claimed that the experience is caused by the world in an appropriate, non-deviant, non-lucky way. When one has an illusion or a hallucination, this is experienced because the subject represents the world to be a certain way when the world is not that way, or if it is that way, it is so by chance.

Externalist versions of representationalism are ones which hold that what it is for a state to represent something is for it to bear a certain relationship to that thing. For example, your experience must track that thing in ideal conditions, or it must have the function of tracking that thing, which it gained by actually tracking that thing in the past and then being selected for on the grounds of the usefulness of tracking that thing. There are different versions of externalist representationalism, but core to them all is the thought that the thing that is represented exists or existed and experiences get to represent that thing by bearing a relationship to it.[35]

Novel colours of the sort that don't actually exist thus pose a problem for this theory. Our experiences of those colours represent those colours, but they can't have been hooked up to instances of that colour in the right way, for such instances don't exist.

Of course, there are ways for externalist representationalists to try to rebut this argument. These are explored at length in Macpherson (2003), but I argue that ultimately experiences of novel colours do present a counterexample to externalist representationalist theories.

The second example is certain versions of naïve realism. To understand what these theories are, I will compare and contrast them to other central philosophical theories of perception.[36]

According to the sense-datum theory, when one either sees an apple, has an illusion as of an apple, or hallucinates an apple, one is in the same mental state—a state in which one is aware of some mental object that has the properties that one seems to be aware of. Such a view is a variety of "common-kind" view, for the same sort of mental state is postulated to exist when veridically seeing (the good case) and when one is undergoing an illusion or hallucination (the bad cases). Some versions of representationalism are common-kind theories—according to them, in the good case and in the bad cases, one is in the same type of mental state: one that represents an apple. Some representationalists have started to distance themselves from this view arguing that there are some mental differences in the good case and the bad cases. Different versions of this view outline different differences, but what they are needn't be a matter of concern here.[37] Views according to which there are mental differences in the good and bad cases are "disjunctive" views and they stand opposed to common-kind theories.

One brand of disjunctivism is not representationalist. According to this view, when one is in the good case one is not in a state that represents the world being a certain way. Instead, one is directly aware of that portion of the world, and not in virtue of being aware of a representation or having a representation. Rather, one is simply directly aware of the world. The world is presented to one, and so a representation of the world in not required. Indeed, when the world is presented to one, the state that one is in could not stand for the way that the world is in a manner that could be judged correct or incorrect, true or false. The state encompasses the world being the way that it is: the relevant part of the world is a constituent of the state. This view is naïve realism, and naïve realists claim that the phenomenal character of your experience is not to be identified with a mental-proxy—a representation, representational content, or sense-datum—rather it is to be identified with the very state of the world itself.[38]

If one gives such an account of the good case, then what account can one give of the bad case? The core thought that forms the answer that disjunctive naïve realists give is that in the bad case you are not in direct contact with the world. In some sense, it seems to you as if you are, but this seeming is incorrect. Because the phenomenal character of the good case is constituted by the world, then the disjunctive naïve realist has to say that the bad case does not involve this phenomenal character. It either involves no phenomenal character, or at least a different one.[39]

Another form of naïve realism abandons disjunctivism and claims that in the bad case one is in the same mental state as the good case—it is one in which one is aware of the world too. How could that be? The answer proffered is that one is aware of previously seen objects and properties.[40]

One can see straight away that the latter non-disjunctive form of naïve realism will fail to account for experiences of these novel colours if it is true that they are not actual, for in that case, they are not seen now, and they have not previously been seen in the past. As previously mentioned, Manzotti (2017), who holds a view bearing a very close affinity to this one, tries to overcome this objection by claiming that if there are experiences of these novel colours then physical objects actually come to have those novel colour properties when they are so experienced. Thus, he overcomes this problem by becoming non-objectivist about colour properties. But this moves Manzotti's view away from a naïve realism, towards a non-realist position.

What of the disjunctive form of naïve realism? Recall that, according to that view, in the bad case it seems to you as if you are seeing the world when you are not. In what sense does it seem to you that way? According to Fish (2009) it seems to you that way because you are in a mental state that has all the same cognitive effects as a state of seeing the world. This view is troubled by these novel colours, for if such colours are not actual, then there isn't a state of seeing the world that is the state of seeing such colours. So, there can't be a hallucinatory state that has all the same effects as this state.

Martin's disjunctive naïve realism is less committal about the nature of hallucinations than that of Fish. On principle, Martin holds a 'negative epistemic' account of hallucinations because he holds that any positive characterization of hallucination leads the disjunctive naïve realist into the screening-off problem. This is the problem of being able to give the experience in the good case an explanatory role—an explanatory role that explains the phenomenal aspects of the experience—that is distinctive from the experience in the bad case, and shows that we need to posit a different sort of mental state in the good case, rather than just the mental state that we posit in the bad case. If one does not need to posit a distinctive good case experience, then the need for the disjunctive naïve realist account of hallucination vanishes. Martin's account of what makes it the case that one's hallucinatory experience is as of an apple is just that it is an occurrence which is indiscriminable from—cannot be told apart, solely on the basis of introspection, from—a veridical perception of an apple.

Can this negative epistemic account of hallucination deal with the sorts of experience of novel colours under discussion—ones that don't exist and must be non-veridical, if we are to remain realists and objectivists about the properties that we take ourselves to perceive? I find this question hard to answer. On the one hand, there seems to be a reading on which it cannot, for if there can be no veridical perception of a certain colour how could one be in a state which is indiscriminable, solely on the basis of introspection, from it—a state that does not (and, depending on your view, perhaps cannot) exist? To see this, consider the following analogy: suppose we are told that there is a creature that lives in the forests of Scotland which is such that it is impossible to tell it apart from a unicorn. And, at the same time, it is true that there are no unicorns. How could there be such a creature? How could it be impossible to tell apart a creature from one that does not exist? What criteria could one use to know whether one had not told it apart, rather than that one had? But, on the other hand, there seems to be a reading on which there could be a state indiscriminable, solely on the basis of introspection, from a state that does not exist, such as a state of seeing reddish-green. If, when you are in that state, you cannot know whether, just on the basis of introspection, you are in it, or in the state of seeing reddish-green, then the actual fact that you must merely be in the indiscriminable state, seems not to matter. One (at least often) does not know, just by introspection, which states of seeing do and do not exist, or could and could not exist.

Which reading should we give of the negative epistemic account, and which reading does the naïve realist intend, or which does he or she have intend to make best sense of their view? These are interesting questions that lie at the very forefront of our thinking about the impact the existence of experiences of novel colours should have on which theories of perception and perceptual experience we should accept.

5 Summary

The topic of novel colours is fascinating. Weighing up the evidence about whether there are experiences of such colours necessarily takes us deep into both philosophical and scientific territory. A detailed understanding of how normal and unusual human colour perception works, and that of other creatures, is essential. And all of this is contested and not yet fully understood. Furthermore, experimental work that has been taken to reveal experiences of novel colours is less developed than we would ideally like it to be.

Nonetheless, there is evidence from multiple empirical sources that there are experiences of novel colours. That such evidence converges is helpful for those who wish to argue that there are such experiences.

If there are such experiences, they present very powerful, interesting examples with which to test, explore, and examine the various theories of colour, colour perception, and perceptual experience of colour, that form the core of philosophy of perception. I have indicated various ways in which this can be done and indicated directions for future study.

Notes

1 Thanks to Derek Brown for very helpful comments on a draft of this chapter.
2 Hume's missing shade of blue is a likely counterexample here, but one that lacks any bite as its novel nature is so slight.
3 This is discussed in section 2.
4 Some metaphysicians hold that properties exist even if never instantiated. That is not the sense of existence that I am interested in contemplating in this chapter.
5 This title is mostly found in popular media. See, for example, Helmsteine (2018) and Wikipedia contributors (2018).
6 See Billock *et al.* (2001), Billock and Tsou (2004) and (2010), and Hsieh and Tse (2006).
7 See Ramachandran and Hubbard (2001).
8 See Ramachandran and Hubbard (2001) and Gatzia (2008).
9 See Churchland (2005), Helmsteine (2018), and Wikipedia contributors (2018).
10 See Ramachandran and Hubbard (2001) and Gatzia (2008).
11 Such after-images are often called 'negative' after-images or 'complementary' after-images, terms which are used to signal that they are induced by a hue on the opposite side of the hue circle, as opposed to 'positive' after-images which are induced by the very same colour. See Macpherson (September 2017).
12 Colours spaces are discussed at length in David Brigg's chapter on that topic in this volume (Chapter 9).
13 See Munsell (1905).
14 Hård *et al.* (1996).
15 Surface colours are colours that are perceived as being on an opaque surface of an object, as opposed to colours seen in translucent volumes or radiant colours. Surface colours are also distinguished from aperture colours. Surface colours are seen in conditions in which it is possible to distinguish the colour of the surface from that of the ambient light. In contrast, aperture colours are perceived by looking though a small aperture formed by an achromatic colour, which makes it impossible to distinguish the colour from that of the ambient light. See Maund (2019).
16 See Churchland (2005) for technical details.
17 See Macpherson (2003).
18 See Broakes (2010) and Byrne and Hilbert (2010).
19 In this chapter, I discuss only the new theory as it pertains to dichromatic colour blindness. However, the interested reader should look at Akins (2014) for a similar new account of rod achromatopsia (the condition of having only the visual system that operates in low light that utilizes rod cells in the eyes rather than the cones cells that we have discussed thus far that operate in greater lighting conditions). In the past this condition has been treated as being monochromatic vision. But Akins' exceptional work drawing on a very detailed knowledge of the latest colour science and what that tells us about the nature of experience argues that it is not like black and white vision.
20 The suggestion that objects can have multiple colours at the same time is explored at length in Mark Kalderon's chapter (Chapter 20) for this volume on "Monism and Pluralism", and in Keith Allen's chapter (Chapter 14) on "Interspecies Variations". Colour relationalists are likely to hold this view—see Jonathan Cohen's chapter (Chapter 19) on "Colour Relationalism" in this volume too.
21 See Stazicker (2018) for an excellent discussion of why the view that we only perceive determinates and not determinables is wrong and why we should hold the view that we see only determinables of one sort or another, rather than determinates.
22 See Keith Allen "Interspecies Variations" (Chapter 14, this volume) for more on animal colour vision. See also Marshall and Arikawa (2014) from whom I take the details of animal colour vision in this section. We also find trichromatic animals whose three different types of cells are attuned to different wavelengths than those of humans: they are shifted towards and into the ultraviolet. I will not discuss this type of colour vision, but it is interesting to speculate what it would be like to have it.
23 See Manzotti (2017: 168) for a table listing many of those who have claimed this, including Macpherson (2013).
24 See Jameson and D'Andrade (1997: 308).
25 See Wyszecki and Stiles (1982: 176).
26 More details can be found of synaesthesia in Berit Brogaard's chapter (Chapter 12) in this volume.

27 Some of this section and the next presuppose the opponent-colour theory that I questioned in section 3.4. I will set aside questioning that theory for the rest of this chapter. First, I have already covered that topic. I leave it to the reader to decide whether anything of substance would have to change in articulating the issues of the rest of these sections in terms of opponent complementary colours, rather than in terms of the traditional opponent colours. I believe it would not.
28 See, for example, Krauskopf (1963) and Yarbus (1967).
29 See Troxler (1804) and Thomson and Macpherson (July 2017).
30 Which colours are isoluminant varies from subject to subject.
31 As noted previously, self-luminous chimerical colours are somewhat different from the other chimerical colours. The other chimerical colours (stygerian and hyperbolic colours) are not colours that any physical object could have. This matter is more nuanced in the case of self-luminous chimerical colours. Of course, physical objects can really be self-luminous and those will typically look the way self-luminous chimerical colours look. What makes a self-luminous chimerical colour is that it looks self-luminous, but it appears to be on the surface of an object that is in fact not self-luminous. I will leave aside this complication in the main text and speak as if all chimerical colours are straightforwardly colours that no physical object can have, and leave out the extra nuance noted here.
32 See Howard Robinson's chapter (Chapter 21) in this volume, "Mentalist Approaches to Colour".
33 The interested reader may wish to consult Gierlinger and Westphal's chapter (Chapter 5) in this volume on "The Logic of Colour Concepts" for further discussion of the modal force of various claims about colour.
34 See Hume's (1740/1978: 6) discussion of the "missing shade of blue".
35 See, for example, Dretske (1995) and Tye (1995).
36 See also Brown and Macpherson in this volume, "Introduction to the Philosophy of Colour", and John Campbell in this volume, "Does That Which Makes the Sensation of Blue a Mental Fact Escape Us?" (Chapter 25).
37 One clear example is Schellenberg (2013).
38 See Crane and French (Spring 2017).
39 See, for example, Martin (2004 and 2006) and Fish (2009).
40 See, for example, Weir (2004), MacGregor (2015), and Manzotti (2017).

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