Painting with impossible colours: Some thoughts and observations on yellowish blue

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Abstract

This paper considers evidence, primarily drawn from art, that one kind of impossible colour, yellowish blue, can be experienced.

Introduction

Impossible colours, also called forbidden colours, are those which combine opponent colours: yellowish blues and reddish greens. Impossible colours are usually held not to exist – they have no part in our experience of colour. This paper examines evidence, primarily from art, that one kind of impossible colour, yellowish blues, can in fact be experienced.

1.

Consider this question, posted to an internet forum by an aspiring painter:

> I have been trying to paint (in real oils and acrylics) a fade from yellow color to blue without going through green, but it's impossible to me, I have no idea how to do it. … how is this possible? I really have no idea, please help. (Christian Ibarra on conceptart.org, 14 May 2008.)

The question is easily dismissed as naïve, and on two counts. First, opponent colour processing forbids colours being processed as, and so experienced as, both yellowish and bluish. (Hering, 1878; Hurvich & Jameson, 1957). This is reflected in the structure of colour spaces. In the colour circle, yellow cannot gradate directly into blue – it must pass through green (or go the long way round, via orange, red and purple). Nor do more complex colour spaces provide such a pathway. Three dimensional colour spaces (e.g. Runge, 1810, Munsell, 1913) allow other routes to gradate from yellow to blue, but these pathways lead through white, grey and black. Modern RGB colour spaces, such as CIE colour space (CIE, 1932), do not allow such a movement either: to go from yellow to blue, one must either go through another hue or white. It is in this sense that yellowish blue is said to be an impossible colour. The second reason the question is readily dismissed is that mixing yellow and blue paint does not, of course, make a yellowish bluish colour. As a subtractive mixture of what in practice are non-ideal colours, it usually makes a rather dull green. So, the correct response to the painter's question appears to be: what you are trying to do is impossible.

But I wonder if the situation is more complex than this, for it turns out that our aspiring painter is trying to reproduce an effect they believe they have *seen* in another picture. They write, "I was trying to imitate this portion of this picture, it's a sky

illuminated by the sun." (Christian Ibarra on conceptart.org, 14 May 2008.) Another painter, responding to this post, goes further – they say that the effect can be seen in nature: "As it happens the sky can often be seen as a gradation going from blue to yellow (vertically downwards)." ('input' on conceptart.org, 14 June 2008.) What are we to make of this? Perhaps they do not realise that the blue and yellow they see in the sky mix in a different way to their blue and yellow paints. While the pigmentary mixture is subtractive, typically producing a dull green, the colours of the sky are beam colours, and mix additively, making white. That suggests the following solution: what they see in the sky is not really blue merging with yellow via yellowish blue, but blue merging first into an area of whitish light, which is seen as a greyish colour, which in turn fades into yellow at the horizon.[1] To depict this, a painter could gradate three horizontal bands of paint into each other: blue merging into white or grey, which in turn merges into yellow. No yellowish-bluish colours are seen, and no such colour needs to be mixed on the painter's palette.

But that explanation does not account for what the painters claim to experience. Their reports – of painting and sky – are not of yellow and blue grading through an area or point of neutral white or grey, or through some other colour, but of yellow grading *directly* into blue, that is to say, through a yellowish blue colour. That too is what they are trying to paint.

2.

I will take these observations of pictures and skies seriously here, and do what I can to evaluate them. I start with the question of whether the sky ever appears yellowish blue.

Consider first some further anecdotal evidence. A writer for NASA's website observes that "[d]ust can fade a blue sky and give it a yellowish or brownish tint … the color changes are sometimes much more obvious near the horizon." (mynasadata.larc.nasa.gov). Does this describe a sky that appears yellowish blue close to the horizon? Perhaps, but it could mean something else – that the sky, which was earlier blue, might now be yellowish, with no hint of blue. Another example is found in a question on the Physics and Astronomy Online forum:

> 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? (Rulon Larsen, Physics and Astronomy Online internet forum, physlink.com)

Again, let me put aside the possible confusion of additive and subtractive mixture to focus on what the writer perceives. Do they imply that they have observed skies that appear to gradate through a yellowish blue? Maybe; but it could also be that they describe a transition through white or grey. (The respondent to the question does not comment on the

[1] There are various ways this transition could be understood. If the gradation is constant, the grey would be coloured slightly blue, passing through a point of genuinely neutral grey, before becoming slightly yellow. Or the gradation might not be constant, in which case it could pass through an area of genuinely neutral grey, Or the grey could be tinged with other colours, passing the long way around the colour circle. The crucial point is that none of these involve a transition through yellowish blue.

“impossibility” of this perception, but focuses on the difference between additive and subtractive mixture.)

Consider a third example, in which the observations are carefully documented. The art historian James Elkins has produced a series of images indicating the colours of sunset in a clear sky (Elkins & Fiorentini, 2020, pp. 115–118; an earlier version of the material appears in Elkins, 2000). He notes that when the sky is clear these colours develop in a fairly predictable pattern, a pattern that is much the same, but reversed, at dawn. Looking east, before sunset, one of Elkins’ annotated images (fig. 1, top) indicates a pale blue appearing to gradate directly into pale orange. Understanding orange to be a yellowish reddish colour, the implication is that these bands gradate into one another via an impossible colour. In his notes to another image, he describes a band of colour observed at sunset as “yellow-blue” (fig. 1, centre). It might be that Elkins has left out or overlooked the white or grey areas in between orange and yellow, and blue. However, he is aware of such subtle effects and takes great care to document them elsewhere. For instance, facing west at sunset, he observes a delicate grey band between blue and orange (fig. 1, bottom).

Figure 1. From Elkins, J., Fiorentini, E. (2020). Visual worlds: Looking, images, visual disciplines. New York, NY: Oxford University Press, fig. 9.1, p. 116. Images indicating bands of colour observed in a clear sky around sunset. Top: Looking east, before sunset. Centre: Looking east at sunset. Bottom: Looking west at sunset.

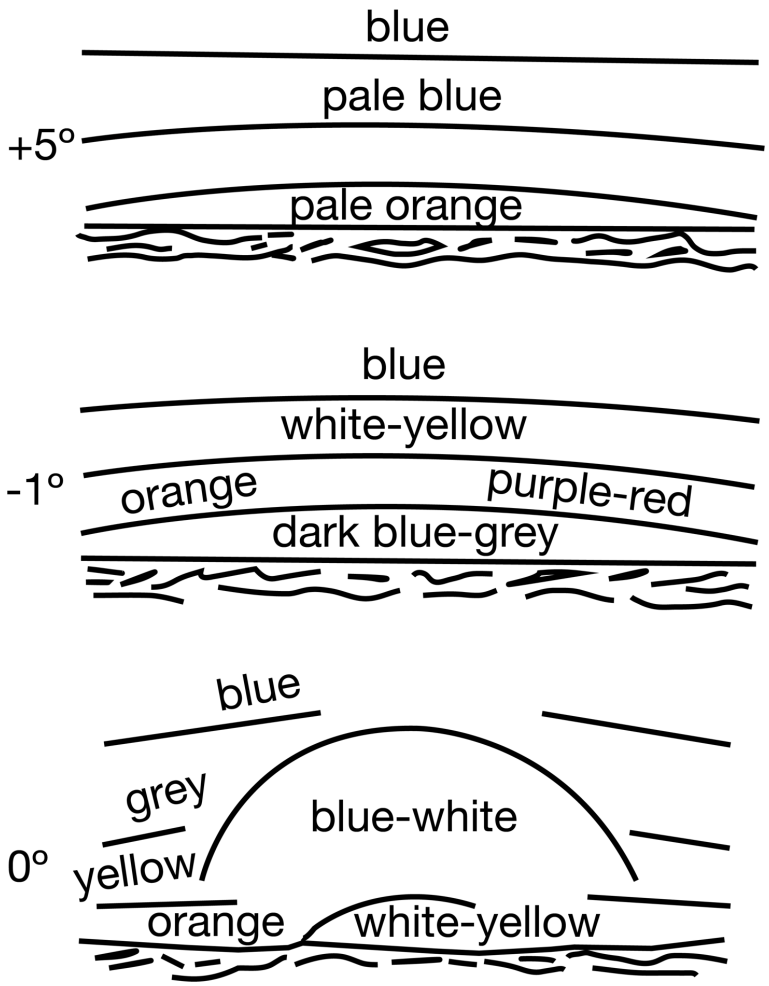

Figure 2. From Minnaert, M. (1993 (1937)). Light and color in the outdoors. Springer-Verlag, details from fig. 169, p. 295. Images indicating bands of colour observed in a clear sky around sunset. Top: Looking east, sun 5° above the horizon. Centre: Looking east, sun 1° below horizon. Bottom: Looking west at sunset.)

It is possible however, to harbour doubts about Elkins’ observations, careful as they are. Elkins was inspired by the observations recorded by astronomer Marcel Minnaert (Minnaert (1993 (1937)). Elkins’ perceptions accord closely with Minnaert’s, except in one crucial respect. In contrast to Elkins, Minnaert *avoids any suggestion that the sky appears yellowish blue.* This can be seen in his illustrations, reproduced in fig. 2, which match the viewing conditions of Elkins’ images. In Minnaert’s top image, blue and orange bands, which Elkins seems to show as blending, are separated by another band of colour (which Minnaert does not name). In the centre image, we see that the band Elkins described as “yellow-blue” is labelled by Minnaert, “white-yellow”. Thus, Elkins’ observations seem to be contradicted by those of Minnaert.

So, can the sky appear as yellowish blue? On the evidence so far: maybe, but maybe not. Anecdotal reports are suggestive but ambiguous, and the more careful observations of Elkins and Minnaert, taken together, are inconclusive.

3.

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I turn now to painting. Landscape paintings depict skies of all kinds, and there are a great many that show clear skies around dawn and dusk: the conditions which, judging from Elkins’ observations, are most likely to provide examples of impossible colours. Painters have depicted twilight effects with some care since Claude Lorrain in the seventeenth century. Claude often painted scenes looking into the sun just before sunset or after sunrise, of which *A Mediterranean Port at Sunrise with the Embarkation of Saint Paula for Jerusalem*, c. 1657, (fig. 3) is a typical example. In these works, Claude depicts skies that are clear but for a few small clouds. They smoothly gradate from hazy blue at the top, to pale yellow at the horizon. J. M.W. Turner is another painter who depicts the same kind of sky. *The Blue Rigi, Sunrise*, 1842, is a good example. Other notable instances are Phillip Otto Runge’s *Morning*, 1808, and Charles Gleyre’s *Evening or Lost Illusions*, 1843. Each shows much the same kind of sky, blue at the top, merging smoothly into yellow close to the horizon.

Figure 3. Claude Lorrain, *A Mediterranean Port at Sunrise with the Embarkation of Saint Paula for Jerusalem*, c. 1657.

With the rougher brushwork of the Impressionists, smoothly gradated skies fell out of vogue in art of the later nineteenth century, and landscape painting itself now has little place in contemporary art. But the art of painting such skies is not lost, as illustrated in an instructional YouTube video by the painter Shaun Ryan. I dwell on this video because I have found that some viewers, although not all, describe it as giving rise to an experience of

yellowish blue where the two colours merge into one another. At this point I ask the reader to the view the video themselves (https://youtu.be/Zr9kMc25bPI).

Figure 4. Shaun Ryan, How to paint a sky – acrylic painting lesson. YouTube, https://youtu.be/Zr9kMc25bPI.

Let me hold back on what viewers may see here, and look first at how Ryan produces this effect. Working with opaque acrylic paints, he starts by painting a horizontal band of white across the middle of the support. Across the top, he applies blue paint, merging it roughly into the white below it. At the bottom, he paints a band of yellow (mixed with a touch of red, giving it an orange tint) which he merges roughly into the white. He smooths the colours and paint surface until the transition between blue and yellow is soft, and the tone is fairly even and light from top to bottom.

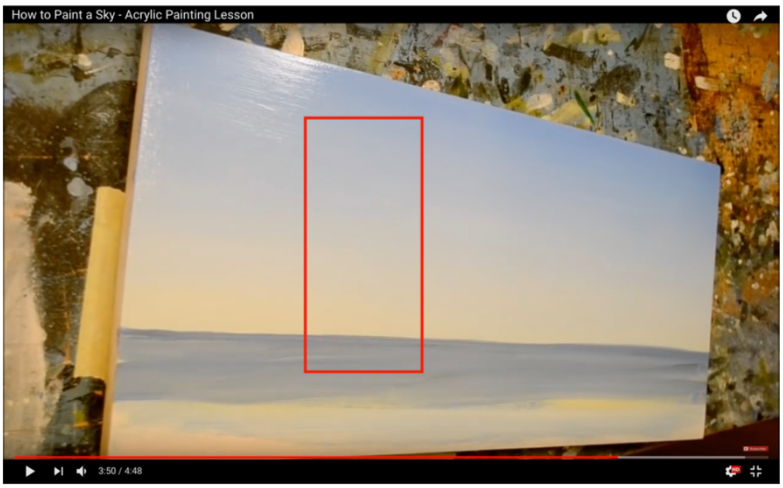
In the area of transition, one can see that blue, yellow and white are mixed together. Occasionally, I have found that some observers see this area as having a greenish tint, but mostly they do not. Of course, the mixture of blue and yellow paints ordinarily makes green, but the video demonstrates that a careful adjustment of these colours can instead produce grey.[2] A number of commenters ask Ryan how he avoids his mixture becoming green. In reply to one he gives this answer:

> If you use a warm blue such as ultramarine, and add a little red to it you will create an almost indigo colour which will not turn green when it blends with the

[2] A subtractive mixture of ideal blue and yellow does make grey. However, an anonymous referee observes that the mixture seen here does not appear to accord with subtractive mixture as described by colourimetry. This would be due to the presence of “hidden variables”, which are not visible in the component colours, but become visible in the physical mixture of paint.

> orange-yellow colours. It will however become greyish and look a bit “muddy” if you overwork it. (Shaun Ryan, reply to comment, ‘How to Paint a Sky – Acrylic Painting Lesson’, YouTube, www.youtube.com/watch?v=Zr9kMc25bPI.)

In response to another, he notes that he adjusts the colours so they “are complementary or quite close to it,” and so “neutralized” by one another (ibid.). Ryan’s remark that the colour mixture is “greyish” is relevant here, for in the area where the blue grades into yellow, the paint is in fact a pale grey. Where it fades into the blue band, this grey paint may be slightly bluish. Where it fades into the yellow, it may be slightly yellowish (perhaps a little brown or “muddy”). But in between it is a neutral grey. This can be seen when the colours are viewed in isolation from their neighbours, as in fig. 5.



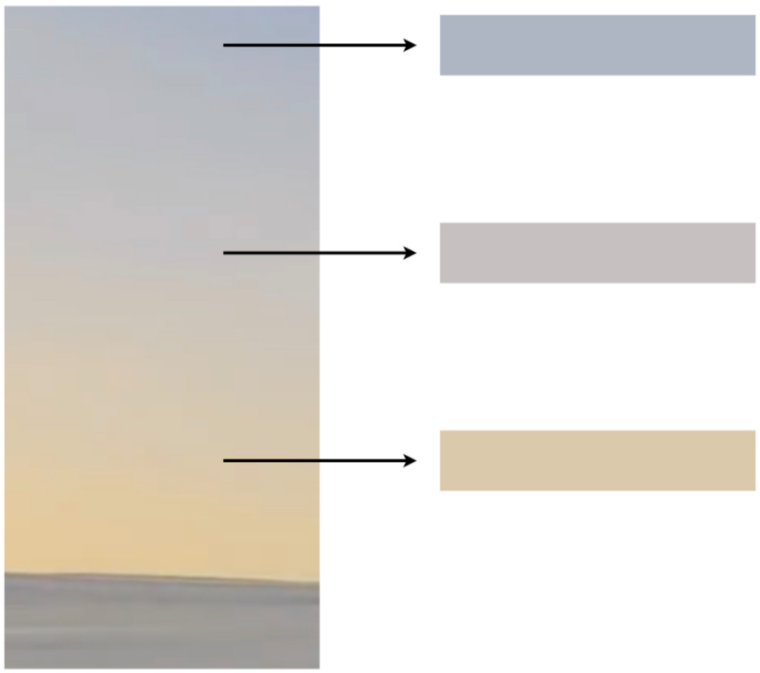


Figure 5. Above: Still from Shaun Ryan, How to paint a sky – acrylic painting lesson, taken at 3:50, with detail reproduced below outlined in red. Below: Detail reproduced from still image above, with areas of colour from this detail isolated at right.

Let me turn now to what observers of Ryan’s painting see. I asked eleven observers to view the YouTube video, projected onto a screen in a darkened room by a NEC ME331W (3300 ANSI lumen) desktop projector. The participants were asked to fixate on a point in the image and indicate on a piece of paper how far up they perceived the yellowish tint on Ryan’s painting, and how far down they perceived a bluish tint. Seven recorded that these yellowish and bluish areas overlapped to some degree, and agreed that they saw a colour that was simultaneously yellowish and bluish in that area. One wrote that “in the middle they get intermingled,” and another described them as “mixed”. One observer described the colour as “yellow/blue pastel”. There was a single report of seeing a transparency effect, so that one colour was seen through the other. This participant described seeing “blue on yellow” towards the top of the image, and “yellow on blue” towards the bottom of the image. I take it that like others’ experiences, the yellow and blue percepts remain phenomenally present in the same part of the visual field, but with an added complexity in that, as Fabio Metelli puts it, the “color splits into two different colors”, so that one “goes to the transparent layer and the other to the surface of the figure below.” [3] (Metelli, 1974, p. 93) (For scepticism about whether this would involve an experience of an impossible colour, see Nida-Rümelin & Suarez, 2009, pp. 362–365). The four observers who did not see the yellowish and bluish areas overlapping described seeing a neutral grey or whitish area – that is, they saw the image as having, at least roughly, the colour the paint does in fact have.[4]

Assuming that the video gives rise to similar colour perceptions as an actual sky, this mixture of results lends credence to reports of yellowish blue skies that I have considered earlier. It also allows the disagreement between Elkins and Minnaert to be resolved, since, like Elkins, some observers in my experiment saw yellowish blue colours, while others, like Minnaert, did not. (As I have said, occasionally, those I have shown this video to report seeing the area as green, but none in this group did so. I have also come across one instance in the literature in which the sky is reported as greenish where the areas of blue and yellow meet. Gruner & Kleinert (1927) describe it this way, and record this effect as a pale green in the illustrations to their book.)

4.

I take it that these perceptions of a yellowish blue are examples of a *filling-in* phenomenon. In the presence of a limited stimulus – here a soft, unmodulated, grey with unclear boundaries – the visual system fills the area in with information from the surrounding, yellow and blue, areas. Like some other filling-in phenomena, it seems to strengthen where

[3] Metelli describes the colour prior to being split as “stimulus color” – that is, local colour, rather than cognitive colour. (Metelli, 1974, p. 93). Metelli’s focus is on achromatic colours, but generally he sees splitting as a reverse of additive mixture. (ibid.) On that basis, it would make sense that a neutral grey can be split into yellow and blue. But it seems to me that it could also be useful to think of a yellowish blue cognitive colour being split here.

[4] In their experiments, which I discuss in section 4, Billock, Gleason & Tsou (2001) found that equiluminance plays a role in promoting the perception of impossible colours. The areas of colour in Ryan’s painting are very close in tone, and it seems likely that helps produce the effect here too. Billock also suggests that this could play a role in some of the differences in viewer response that I found: “It may be that one source of individual differences in some experiments is that for some subjects the colors used were approximately equiluminant to them, whereas for other observers there was a significant luminance difference”. (Billock, personal communication). Some of Billock, Gleason & Tsou’s observers also observed a transparency effect.

the stimulus has smooth, unclear boundaries, and as one looks at the stimulus (e.g. Kanai & Kamitani, 2003; Troxler, 1804). The latter point perhaps explains why Ryan’s video, which requires the viewer to spend time with it, is a relatively effective way of inducing this effect.

The yellowish blues I have discussed here are a delicate effect. Others have claimed that stronger yellowish blues (as well as reddish greens), can be induced by different means. Crane & Piantanida (1983) used eye-trackers to achieve this, stabilising fields of opponent colours until the perception of their edges fades. They also attributed the reported perceptions of impossible colours to a filling-in phenomenon. Billock, Gleason & Tsou (2001) performed a similar experiment, obtaining similar results. (Other approaches have achieved less strong effects, perhaps comparable to my own. Livitz et al. (2011) use the interaction of neon colour spreading and chromatic contrast to induce perception of impossible colours. Billock & Tsou (2010) add to their earlier work a finding by Jeff Hovis, that binocular vision provides an easier, albeit less reliable, way to experience impossible colours: to see yellowish blue, allow one’s eyes to cross while observing a diagram that shows a blue field to one eye and a yellow field to the other.[5]

These claims have not gone uncontested. Hsieh & Tse (2006) have found that observers who took part in experiments similar to those of Crane & Piantanida and Billock, Gleason & Tsou were able to match the colours they experienced to those available in CIE colour space. They concluded that the subjects of these experiments were therefore not experiencing impossible colours. However, Hsieh & Tse used steady fixation, rather than the image stabilisiation of earlier studies. Steady fixation generally produces weaker results than stabilisation (Ditchburn, 1973), and Billock observes that the results are indeed weaker here: “although I saw yellowish blues and bluish yellows many times under stabilization, I never saw them under steady fixation.” (Vincent Billock, personal communication). My experiment also makes use of steady fixation, but it too can be defended from criticisms that matching colours could be picked out of CIE colour space. When my observers reported yellowish bluish colours, they identified them by distinguishing them from the neutral colours that would be the obvious contenders for matches in CIE colour space – i.e. subtle greys tinted with blue or yellow.

How can my results be squared with the opponent theory of colour vision? The existence of such colours is incompatible with the idea that opponent processes wholly determine colour experience. Two ways have been proposed to resolve this. For Crane & Piantanida, impossible colours leave opponent processing undisturbed. Rather, they are explained by the fact that opponent processes only play one part in determining colour experience. Processes of filling-in, which happen elsewhere in the visual system, play another important role. According to Piantanida:

> Filling in … seems to “paint” colors and patterns across areas of the visual scene for which there are apparently no signals emanating from the retina. … When we provided conflicting information at that boundary – for example, red on one side and green on the other – the filling-in mechanism “painted” both colors across

[5] Vincent Billock notes that the attribution to Jeff Hovis was unfortunately omitted from Billock & Tsou (2010) due to a copy editor’s error made while editing the article for length. The article should have credited a personal communication from Hovis. (Billock, personal communication)

> the perceptual field. These results … suggest that the filling-in mechanism functions according to its own rules, independent of color-opponent retino-cortical pathways. (Piantanida, 2010, p. 5)

Billock and his colleagues give an alternative account in which impossible colours are evidence that opponent processes are misunderstood: they propose that colour opponency could be based on softwired Winner-Take-All competition among cortical colour mechanisms and that this competition can break down under some conditions, disabling opponency (Billock et al., 2001; Billock & Tsou, 2010). In any case, it is clear that there is scope for accounts of visual processing that allow impossible colours to be experienced.

Conclusion

There is, of course, no yellowish blue paint. But some viewers can see paint as having this colour. That is a kind of optical illusion: on Piantanida’s account, filling-in “paints” these colours across the perceptual field; for Billock et al. these colours can be thought of as “painted” by another process. Whatever its explanation, this illusion has been exploited by artists, who show us that the “painting” done by the visual system has also allowed them, in a sense, to paint with impossible colours.

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