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The Colours of Transparencies

I need help with some interior design. I like green glass bottles, and want to hang ten of them on my wall. I'm also a stickler for colour coordination, so want to paint the walls to match. Which paint should I choose? I think the closest match is bottom row, second from the left, in Figure 1b. But something seems off; the colours seem different somehow.

Figure 1. (a) green glass bottles, (b) green paint samples.

This paper argues that the difference is real: the bottle and paint are perceptually attributed different colours. Generalising, the negative thesis is *Uncommon Colours*: things that visually appear transparent (*perceived transparencies*) cannot be perceptually attributed the same colours as things that appear opaque (*perceived opacities*). The positive thesis is *Clear Colours*: perceived transparencies are attributed colours that can be characterised by an achromatic dimension running from black to clear or perfectly transparent, rather than black to white. Surprisingly, then, clear turns out to be a limit achromatic colour. This upsets orthodox perceptual theory, which sets the colours apart from respectable material features like transparency and opacity.[1] It also indicates that colour perception is more closely connected with the perception of space and form than is often assumed.

A clarification, before we begin. In talking of perceptual attribution, I am highlighting cases where transparent objects are perceptually discriminated, thus represented apart from their backgrounds, and characterised by general elements of representational content, or attributives.

[1] For example, see Evans (1974: 90-92), Westphal (1986: 313, 316), Fairchild (2005: 141-144), and Choudray (2014: 122).

Physically transparent things often are not represented as objects in this way. Take the air, for example, or lenses of sunglasses being worn. It is important, then, to distinguish such physical transparency, from *perceptual transparency*, which implicates a perceptual object representation that assigns features like shape, size, motion, and – importantly – colour.[2] This paper concerns perceptual transparency, though our understanding of physical transparency will be relevant at times.

Here's the plan. Section 1 discusses motivations for the orthodox view, Common Colours. Section 2 argues for Uncommon Colours, and Section 3 for Clear Colours. Section 4 ties things together. Let's go.

1. Common Colours

In philosophy of perception, the orthodoxy is *Common Colours*: perceived transparencies and opacities can be attributed the same colours.[3] Westphal (1986: 313, fn. 6), for example, claims that 'it is surely a grammatical mistake to speak, as Katz and others do, of surface, film, and volume *colours*. Blue, for example, is or can be all three.'[4] Byrne and Hilbert (2003: 11) similarly claim that,

> Opaque objects, translucent [i.e., transparent] objects, and light sources can look the same in respect of colour. Therefore, the natural inference is that there is a single property that vision represents all these objects as having – a conclusion supported by common speech, as well as by what is known about the extraction of colour information by the visual system.

The point about common speech is well-taken. We describe the glass bottle as light green, just like the paint sample. Transparent liquids and acetates come in red, yellow, orange, pink, and more. We also apply some achromatic colour terms, calling the car window in Figure 2a 'grey,' just like the slate

[2] The distinction is due to Metelli (1974: 91), and informs all subsequent scientific work on transparency perception. Mizrahi (2018: 245-246) rejects the distinction. Mizrahi (2018: 243) claims that 'transparency and invisibility are essentially connected,' hence that 'all transparent objects are invisible.' I discuss Mizrahi's view in section 3.
[3] One exception is Paul Churchland (2007: 148), who distinguishes families of 'reflective,' 'self-luminous,' and 'transmittance' colours. Churchland's argument focuses on reflective and self-luminous colours, however, discussing transmittance colours only in passing.
[4] Cf. Wittgenstein (1977: I.45, II.76, III.242). 'Blue' can pick out a colour – a quality with (at least) three dimensions of variation, including hue – or just a hue. Common Colours concerns perceived colours, not just hues. I take this to be Westphal's view, given his emphasis on '*colours*.' As Matthen (2020: 167) stresses, '*hues* are not colours.' [BLINDREF].

chips in 2b. Assuming that we use colour language to convey how things visually appear to us, this usage provides some support for Common Colours. For applying the same colour terms thus suggests the same colour appearances; hence, presumably, same perceived colours.[5]

Figure 2. (a) car window, (b) slate chips.

A deeper motivation for Common Colours concerns our concepts of colour and transparency-opacity. In ordinary language and thought, 'transparent' means 'see-through,' and 'opaque' means 'not see-through.' I won't attempt to give the meaning of 'green' or 'colour.' It is natural to assume, though, that a meaning-specification would not mention 'see-through' or its negation. This suggests that someone competent with the concepts GREEN and COLOUR need not be competent with the concepts TRANSPARENT or OPAQUE. This supports Conceptual Independence, the claim that our concepts of colour and transparency-opacity are independent.

Conceptual Independence does not entail Common Colours, as it concerns conceptual, not perceptual, representation. It provides some support, however, given that these concepts are observational, or applied on the basis of how things look. Ex hypothesi, competence with GREEN does not require competence with TRANSPARENT or OPAQUE. Consequently, someone who has mastered GREEN may competently apply it to an object, yet have no inclination to apply TRANSPARENT or OPAQUE to that object. Given that GREEN and TRANSPARENT/OPAQUE are applied on the basis of how things look, and the subject has mastered GREEN, this suggests that

[5] Wittgenstein (1977: III.151) notes that terms like 'amber' apply only to transparent bodies, not opaque surfaces. As discussed later, the converse holds for 'white.'

looking green is neutral as between looking transparent or opaque. This supports Common Colours, as it implies that perceived transparencies and opacities can have the same green look.

Further motivation comes from Qualitative Independence, the claim that colour qualities are independent of transparency-opacity qualities. The background theory assumes that families of sensible qualities – colours, shapes, tastes, sounds, etc. – are defined by their relations of similarity and difference.[6] To be a colour is (at least in part) to be similarity related to other colours. It is plausible, though, that transparency-opacity qualities are not similarity related to the colours. For it seems strange, if not nonsensical, to ask whether red is more similar to transparent than opaque. This seems like asking whether red is more similar to square than circle, or sweet is more similar to loud than quiet. This supports Qualitative Independence, as it suggests that colour and transparency-opacity qualities are disconnected, thus forming disjoint families, like colour and shape, or taste and sound.

We can frame this in terms of *psychological colours spaces*, which are abstract geometrical representations of similarity relations among perceived colours.[7] Points in such spaces represent determinate types of perceived colour, and dimensions represent ways or respects in which these colours are similar and different. Qualitative Independence amounts to the claim that no such space represents similarities along the dimension of transparency-opacity. This is borne out by research on psychological colour spaces. There are many such spaces, each emphasising subtly different aspects of perceived colour.[8] Since the mid-Eighteenth Century, though, the canonical form of representation has been a three-dimensional space, or 'colour solid.' Suffice to say, no extant colour solid has a dimension for transparency-opacity. That means you can permute perceived transparency-opacity qualities, while holding fixed your location in colour space, which gets you Common Colours.

To make things concrete, take the *Natural Colour System* (NCS), which formalises Hering's (1905/1964) opponent colour theory. This psychological colour space is widely adopted by

[6] Philosophical discussions include Goodman (1951), Clark (1992: 76-116), and Matthen (2005: 95-122).
[7] Following Kuehni and Schwartz (2008), I distinguish these from *psychophysical* colour spaces, which represent colour stimuli, not perceived colours. I discuss psychophysical colour spaces in section 3.
[8] For discussion, see Westphal (1987: 95-99), Kuehni & Hardin (2010: 82-83), and Matthen (2020: 162ff).

philosophers. Matthen (2020: 172), for example, says that 'probably, [the NCS] is philosophically the most neat and tidy way of systematizing colour appearance.' The NCS posits four *chromatic primaries* – red, green, yellow, and blue – and two *achromatic primaries* – white and black.[9] These are 'primaries,' in the sense that it is possible to perceive instances of each that involve no trace of any other colour. Red and green, and yellow and blue, are *opponent*, in the sense of mutually exclusive. Subjects perceive no colours characterizable as reddish-green or greenish-red, for example.[10] The NCS represents this by placing these primaries opposite each other on the hue circle, as in Figure 3b. This circle defines the *hue* dimension of the NCS solid in Figure 3a. Hue values are given by percentages of two non-opponent primaries. The colour triangle in Figure 3c represents colours with 80% red and 20% blue ('R20B') hue.

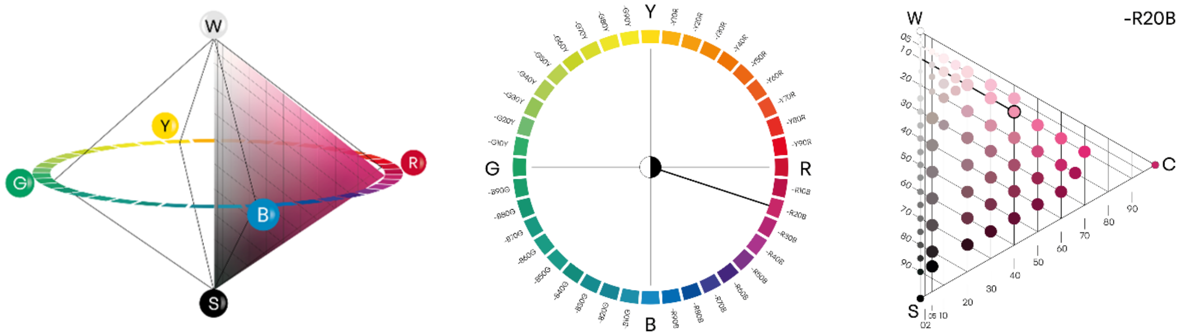

Figure 3. (a) NCS solid, (b) hue circle, (c) colour triangle. Source: https://ncscolour.com/en-int/pages/the-system

The achromatic primaries form limits of the vertical *blackness* dimension, with values ranging from 0-100. These primaries are non-opponent, in that subjects perceive colours characterizable as blackish-white and whitish-black. These colours comprise the *NCS greys*. For instance, an NCS light grey with value 30 is characterised as 30% black and 70% white. In Hering's (1905/1964: 31) words, 'all grey colours are related to the extent that they remind us simultaneously of black and white… we can say that every grey is at the same time whitish and blackish.'

[9] The NCS labels black using '*s*,' for the Swedish '*svart*.'
[10] For enlightening discussion, see McLaughlin (2002: 113-114, fn.38). For a critique of opponent colour theory, see Conway et al. (2023).

Finally, the *chromaticness* dimension defines the distance from the vertical axis, from 0 for achromatic colours, to 100 for pure chromatic colours. The more chromatic a colour, the more saturated with hue; the less chromatic, the more the hue is 'veiled' by grey. The pink circled in Figure 3c has 40% chromaticness, thus 60% greyness. Overall, then, it is characterised as 32% red, 8% blue, 6% black, and 54% white.

As per Qualitative Independence, the NCS has no dimension representing transparency-opacity. As per Common Colours, many proponents of the NCS take it to represent the perceived colours of transparencies, as well as opacities. Hering (1905/1964: 25) claimed that the NCS provided a 'systematic perspective' on '*every colour*' that can be perceived. In a survey of colour systems, Kuehni and Schwarz (2008: 92) concur that 'it is very likely that the psychological primaries are, as Hering indicated, black, white, yellow, red, blue, and green, and these can be used to at least partially describe any colour experience.' Hardin (1988: 116) takes the NCS to represent 'some of the phenomenal relations that obtain among related colours,' which are perceived in contexts where other objects are visible in the background or surrounds. This encompasses colours perceived in the surface and volume modes, thus includes the perceived colours of transparencies.[11] It excludes only 'unrelated colours,' which are perceived in the aperture mode, as when viewing a stimulus through a reduction tube, or otherwise without spatial context, wherein the object appears self-luminous. The NCS thus provides a useful foil in critiquing Common Colours.

2. Uncommon Colours

Common Colours is orthodoxy, then, and seemingly for good reason. I want to convert you to Uncommon Colours. Here is the argument:

1. The perceived greys of opacities can be characterised as mixtures of white and black.
2. Perceived transparencies cannot appear white.

[11] See also Byrne and Hilbert (2003: 13) and McLaughlin (2002: 131). Hård et al. (1996: 185), in contrast, take the NCS to represent only the perceived colours of opacities.

3. If perceived transparencies cannot appear white, they cannot appear colours that can be characterised as mixtures of white.
4. Therefore, perceived transparencies cannot appear the same greys as opacities.
5. If perceived transparencies cannot appear the same greys as opacities, they cannot appear the same chromatic colours as opacities.
6. Therefore, perceived transparencies cannot appear the same chromatic colours as opacities.

Premise 1 follows the NCS in claiming that the perceived achromatic colours of opacities can be characterised as mixtures of white and black. Given that the NCS is widely endorsed by philosophers, including several prominent advocates of Common Colours, this should be uncontroversial.[12] All the same, here are two points in its favour.

First, the premise is quite weak, claiming only that these colours can be characterised this way, not that they must be. That is, it does not assume that the NCS is a definitive or exhaustive representation of these colours. As above, other representations may emphasise different aspects, besides relative proportions of white and black. Premise 1 assumes only that, for all perceived objects, if the object appears opaque and achromatic, then the NCS blackness dimension represents an aspect of its perceived colour.

Second, there is empirical evidence that subjects find it natural and easy to describe perceived colours in these terms.[13] Hård and colleagues (1996: 190) instructed forty naïve subjects to assess fourteen achromatic samples, in terms of their resemblance to their 'own conception of the nonchromatic colours pure black (*S*) and pure white (*W*).' The samples were pieces of cardboard coated with matte acrylic paint. Their answers were to be expressed as values between 0 and 100, such that $S + W = 100$, as per the NCS blackness scale. Subjects showed no difficulties in performing

[12] Among psychologists, Munsell's (1905) system is more influential. Munsell (1905: 13) endorsed Common Colours, claiming that 'all our colour sensations are included in the colour solid. None are left out by its scales of hue, value, and chroma.' The achromatic scale, value, is glossed as 'the quality by which we distinguish a light colour from a dark one,' ranging between the 'extremes of white and black,' (1905: 14). In this respect, Munsell value is similar to NCS blackness. It is unclear, however, whether Munsell's system is a psychological space, rather than psychophysical. For discussion, see Sivik (1997: 167).
[13] Cf. Byrne & Hilbert (2003: 14). For further discussion, see Sivik (1997), Kuehni & Schwarz (2008: 100-113), Hardin (1988: 116-121), Allen (2017: 88, 121-128, 142-146), and Matthen (2020: 164-166).

this task. There were also high levels of inter-subject agreement, with a 95% confidence interval of less than 5 on the 100-point blackness scale.

Shamey and colleagues (2011) ran similar experiments on subjects with minimal exposure to the NCS. They asked subjects to describe opaque stimuli using any suitable combination of chromatic and/or achromatic NCS primaries. In contrast to Hård and colleagues, they found significant inter-subject variation in descriptions of achromatic stimuli, though still markedly lower than for chromatic stimuli. Around half the time, subjects mistakenly included chromatic primaries in their descriptions of achromatic stimuli. The experiment included only three achromatic samples, however, randomly interspersed with sixteen chromatic samples, which might explain this finding. In any case, there is no evidence that subjects ever excluded an achromatic primary when describing achromatic stimuli. This suggests they found it natural to specify perceived achromatic colours of opaque stimuli using proportions of white and black.

One might object that these data do not strictly show that these colours can be characterised as 'mixtures' of white and black.[14] Hård and colleagues (1996: 190) instructed subjects to describe the degrees to which samples 'characteristically resemble' white and black. Sivik (1997: 174–5) likewise reports that 'the phenomenological basis of Hering's postulates… is that all colours can be described in terms of resemblances to these six elementary colours.' The reported resemblances, however, need not be explained by any complexity or compositeness in the perceived colour, as implied by 'mixture.' As Allen (2017: 124) notes, the resemblances might be considered basic, hence 'not to be further explained in terms of anything else.' Call this *Basic Resemblance*.

One issue with Basic Resemblance is that any two colours may be considered similar in some respect or other. Two perceptibly different shades of grey may be classed as equally similar to white in respect of being colours of pigeons, or among Granny's favourite colours, and so forth. Basic Resemblance thus needs to specify which resemblances characterise perceived colours. Allen (2017: 126) suggests that only 'genuine' or 'natural' resemblances play this role, those holding 'in virtue of

[14] Cf. Matthen (2020: 166-167).

the[] intrinsic or essential natures' of the colours.[15] If 'in virtue of' is cashed out in terms of grounding, this creates some tension with Basic Resemblance. For many consider grounding to be a form of metaphysical explanation. On this reading, then, Basic Resemblance does not obviate the need for explanation, so much as shift the explanatory burden to the metaphysics of colour.

I prefer to stay neutral on colour ontology, thus on Basic Resemblance. Fortunately, if preferred, one can easily modify premise 1 to comport with Basic Resemblance:

> 1*. The perceived greys of opacities can be characterised by their genuine resemblances to white and black.

Premise 3 can be amended accordingly:

> 3*. If perceived transparencies cannot appear white, they cannot appear colours that can be characterised by their genuine resemblances to white.

The argument goes through with premises 1 and 3, or 1* and 3*. I shall continue developing the former premises, though address the latter where relevant.

Moving on, sunglasses come in many colours: grey, red, blue, and more. They do not, however, come in white. White lenses certainly would shield your eyes from the sun, but at the cost of opacity. Indeed, it is hard to conceive of something white with any significant degree of transparency. Media like frosted glass and mist are white and partly see-through, but they significantly blur things behind. They are translucent, not transparent. Plausibly, no perceived transparency can appear white, as per premise 2.[16]

This point famously preoccupied Wittgenstein (1977: §I.21),

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[15] Cf. Johnston (1992: 240) and Pautz (2006: 538).

[16] As Wittgenstein (1977: III.146) notes, 'a body that is actually transparent can, of course, seem white to us; but it cannot seem white and transparent.'

> Runge: "If we were to think of a bluish-orange, a reddish-green, or a yellowish-violet, we would have the same feeling as in the case of a southwesterly northwind.... Both white and black are opaque or solid.... White water which is pure is as inconceivable as clear milk."

Wittgenstein used aphorisms like these to illustrate the complexities of colour language, and the 'logic' or 'grammar' of our colour concepts. Transposed into the present framework, the relevance is that Wittgenstein took the impossibility of transparent white, inter alia, to undermine Conceptual Independence. As Marie McGinn (1991: 446) puts it,

> our colour concepts interact in a complex way with concepts like transparency and reflection, which require the notion of three-dimensionality or depth, [showing] that our ordinary colour concepts are not independent of spatial ones.

In particular, someone competent with WHITE knows only to apply it to opaque things. Competence with WHITE thus implicates competence with OPAQUE, contrary to Conceptual Independence.

Significantly, though, Wittgenstein did not take this to undermine Qualitative Independence. Wittgenstein (1977: §I.45) says that 'opaqueness is not a *property* of the white colour. Any more than transparency is a property of the green.' The glass bottle appears green, and it appears transparent, but it does not appear transparent green, in the sense of some distinctive, transparent type of colour. Likewise, snow appears white, and it appears opaque, but it does not appear opaque white, in the sense of some opaque type of colour. Colours per se do not vary in respect of transparency-opacity. This fits Qualitative Independence, as it suggests that transparency-opacity is not a dimension of perceived colour.

This point is key, as if the impossibility of transparent white does not undermine Qualitative Independence, it need not undermine Common Colours. For this allows that the incompatibility between white and transparency is atypical, and not indicative of any systematic, structural relations between colour and transparency-opacity qualities. The incompatibility may thus be presumed to have some non-structural, non-qualitative explanation. This allows that perceived transparencies and opacities can be attributed the same colours, as per Common Colours, except for white, which is atypical in precluding transparency. Call this *Exceptionalism*.

This provides context for work by Westphal (1986, 1987) and Hardin (1985, 1989). These authors endorsed Exceptionalism, but thought Wittgenstein had not provided a satisfactory explanation as to why white, specifically, precludes transparency. In typically oblique fashion, Wittgenstein 'explained' this by describing the interconnected uses of the concepts, WHITE and OPAQUE. Westphal and Hardin wisely looked instead to colour science. Hardin (1985: 119), following Westphal (1986),[17] claims that white is 'unique among the colours of the surfaces of objects in that it alone involves another surface property, diffuse reflectance.' To clarify, reflection and transmission can be either specular or diffuse, as shown in Figure 4. Specular reflection is well-behaved, with light reflected at the same angle as it arrives at the surface. Diffuse reflection rebounds in random directions. Specular transmission is also well-behaved, with light passing through the medium at an angle dictated by Snell's law.[18] Diffuse transmission passes through at random angles. The things we call 'transparent' are good specular transmitters of light. Just as specular reflectors or mirrors preserve the images of things in front of them, specular transmitters preserve the images of things behind, allowing us to see through them.[19] Many white things are diffuse reflectors, as Hardin claims. Some are diffuse transmitters, however, as with milk, opal glass, and frosted acrylic. Abstracting, white things are just very good at scattering light, typically somewhere north of 60-70% of incident light at all wavelengths in the visible spectrum. At the limit, a hypothetical pure white object would be a perfect scatterer of light. As scattering is antithetical to specular transmission, white things cannot be transparent.

[17] Hardin (1985: 199, fn.2) notes a debt to a draft manuscript of Westphal (1986). For further development of Exceptionalism, see Westphal (1987, 2012) and Dedrick (2020).
[18] Snell's law states that the ratio of the sines of angle of incidence and angle of refraction is equal to the ratio of the refractive index of the second medium to that of the first medium.
[19] Gert (2006) defends an analogue of Uncommon Colours for the perceived colours of mirrors. Unfortunately, issues concerning mirrors lie outside the present scope.

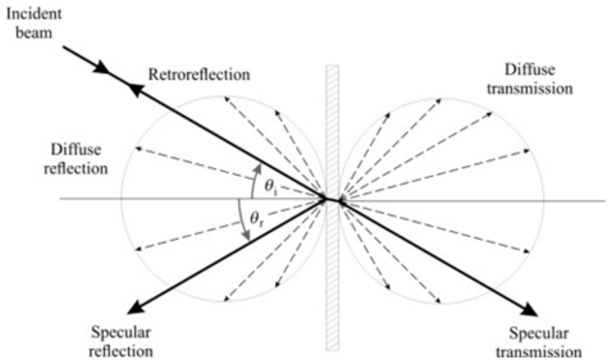

Figure 4. Types of Reflection and Transmission. Source: Höpe (2014)

This is, we should all agree, an excellent explanation of the impossibility of transparent white. It is, in Hardin's (1985: 117-118) phrase, also a purely 'objectivist' explanation: it is not 'subjective in any deep sense. It is, rather, directly related to the optical characteristics of the surfaces.'[20] The explanation is not 'subjective,' as it does not concern the qualitative character of the colour, white.[21] White 'involves' scattering and opacity, only in the sense that these are normal causes of perceptions of white. Consistent with Qualitative Independence, then, white is not similarity related to opacity: it is merely causally related. Importantly, moreover, white is considered 'unique' in this respect, as per Exceptionalism. Common Colours still holds for every other colour: perceived transparencies and opacities can be attributed the same reds, greens, pinks, and greys. In Hardin's (1985: 119) words, although nothing transparent can appear white, 'the conceivability of grey transparencies is not at issue.'

Contrary to Exceptionalism, though, perceived transparencies and opacities cannot be attributed the same greys. I have argued that the perceived greys of opacities can be characterised as mixtures of white and black. Light NCS greys contain significant proportions of white, and even dark NCS greys contain a little. There is reason to think, though, that if perceived transparencies cannot be attributed white, they cannot be attributed colours that can be characterised as mixtures of white,

[20] Green (forthcoming) adopts a similar optical-computational approach to explain other 'laws of appearance.'
[21] To be clear, neither Hardin (1988) nor Westphal (1986, 1987) claims that white can be reduced to some diffuse reflectance property.

either. That is premise 3. If that's right, then perceived transparencies are not attributed the same greys as perceived opacities, as per premise 4.

I develop these points by appealing first to phenomenology, then optics. Consider the series of achromatic filters in Figure 5a. Focus on the right-most filter, and consider its colour: the *filter colour*. We would call this 'light grey.' If this were an NCS light grey, it should seem to contain a significant proportion of white, like the paint sample second from the right in Figure 5b. I suggest, however, that when one introspects the filter colour, it does not seem to contain a significant proportion of white. For if it did, and one were to increase the perceived proportion of white a little, one would arrive at pure white. Conversely, if one were to perceive pure white, and then increase the black content a little, one would perceive the filter colour. Neither scenario seems plausible, however.[22] The filter colour does not seem a mere black-step away from pure white. It seems a black-step away from perfect transparency.

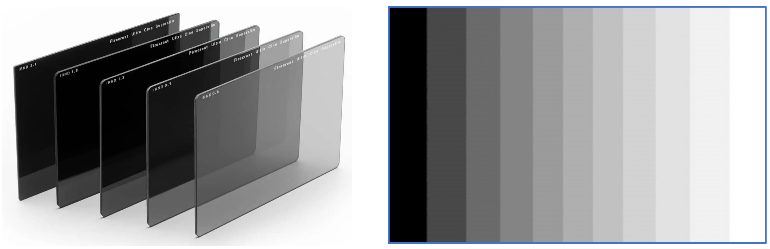

Figure 5. (a) achromatic filters, (b) achromatic paints.

One cannot defuse this point by invoking Basic Resemblance. For there is equally strong reason to think that if perceived transparencies cannot appear white, they cannot appear colours characterised by genuine resemblances to white, either. As above, if the filter colour were an NCS light grey, it should seem to bear a strong, genuine resemblance to pure white. I do not know how to assess the 'intrinsic or essential nature' of a colour, hence its genuine resemblances. (Does anyone, really?) In argumentative spirit, though, let us assume that if such genuine resemblance holds, then one can know that it holds, simply by introspecting the character of visual experiences that represent

[22] Similar points apply to the perceived 'greys' of shadows. For relevant discussion, see Chalmers (2006), Hilbert (2005), and Jagnow (2010).

the filter colour. This follows Byrne and Hilbert's (2007: 77) principle of *Self-Intimation*, which holds that 'if it is in the nature of the colours that p, then after careful reflection on colour experience it seems to be in the nature of the colour that p.'[23] Having reflected on my experiences of the filter colour, it seems to me unclear, at best, whether this colour genuinely resembles pure white. I can reel off many ways in which the filter colour does resemble white, such as being aesthetically uninspiring; but none obviously seems grounded in the nature of the colour. I am, therefore, not in a position to know that such genuine resemblance holds. By the previous assumption, the filter colour does not genuinely resemble white.

This may seem too quick. For there are ways of viewing the filter, whereby the colour perceived does seem to contain a significant proportion of white. Focus on the part of the filter through which you have an uninterrupted view of the background. Fixate the vertical contour formed between the filter and background, and zone out from the other parts of the scene. You should perceive a surface with a colour that contains lots of white, and a little black. I predict, though, that this surface will appear completely opaque; like a patch of grey paint in the same plane as the background. And of course, it is! It is part of a picture of some filters, not an actual filter. The point at issue, though, concerns the perceived colour of the depicted filter, not the depicting surface. To probe this, one must perceptually 'scission' the image, so it seems as though there is a transparent filter lying over a white background.[24] When viewed this way, any whiteness that you perceive should appear to belong to the background, not the filter. Indeed, for the scission to succeed, it is critical that this whiteness not appear to belong to the filter; for then the filter would appear opaque, and you would have no perceptual transparency.

It might be countered that the best way to determine the colour of a filter is to hold it up against a white background, and see how the filter affects its appearance.[25] Wittgenstein (1977: I.24) suggests that, 'if I say, "I am looking for glass of *this* colour" (pointing to a piece of coloured paper),

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[23] This is taken to be one of two principles entailed by Johnston's (1992: 223) statement of '*Revelation*.' See Allen (2017: 131-154) for insightful discussion.
[24] Brown (2014: 14-17, 19) offers helpful discussion of the distinction between colour 'scissions' and 'fusions.' The term 'scission' originates with Koffka (1936a); Katz (1911/1935: 7-9, 92) used the term 'severance.'
[25] [BLINDREF].

that would mean roughly that something white seen through the glass should look like my sample.' Now, imagine viewing some white paper through the light grey filter. The paper may look exactly similar to one of the grey paint samples, thus highly similar to white. This does not show, however, that the filter is perceptually attributed the same colour as the sample. Consider this: white paper seen through clear glass looks white, but this should not lead us to conclude that the glass itself looks white.[26] For if the glass appears transparent, it cannot look white. Wittgenstein's rubric is thus inapt, in general, for determining the perceived colours of transparencies. The reason is that it draws attention to how 'something white… should look' when viewed through the glass, not how the glass would look, when backgrounded by white. This invites subjects to perceptually 'fuse' the colours of the glass and background, to use Metelli's (1974: 91) term, rather than scission them. Such fusion undermines perceptual transparency, however, and thus diverts from the issue at hand.[27]

I now present two optical motivations for premise 3. Ex hypothesi, a pure white thing is a perfect scatterer of light. It stands to reason that an object with a colour slightly darker than pure white on the NCS scale – say, 99% white, 1% black – should do an awful lot of scattering. Similarly, something around mid-grey on the NCS scale should cause moderate scattering; and so on. Now, suppose the right-most filter appeared NCS light grey, and that this perception was caused in the normal way. This predicts that the filter should scatter plenty of light. But the filter is almost completely transparent, hence scatters almost no light. The supposition thus severs the proposed causal-explanatory link between white and scattering, thus opacity. Advocates of this explanation, including Hardin and Westphal, therefore should reject the supposition: the right-most filter does not, after all, appear NCS light grey.

The point can be argued another way. Exceptionalism holds that white is unique in being causally linked to scattering, hence opacity. In reality, though, nothing perfectly scatters light. Even

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[26] Cf. Wittgenstein (1977: III.183, III.200).

[27] Cf. Westphal (1986: 321). Consider an analogous rubric for determining the colour of the illumination: '"I am looking for illumination of *this* colour," (pointing to a piece of coloured paper), means roughly that something white seen under this illumination should look like my sample.' Now, given that something white seen under neutral illumination looks white, the rubric implies that we should class such illumination as white. Indeed, since Newton, this has been called 'white' light. Clearly, however, neutral illumination does not look white, in the way material things look white.

paradigm white objects absorb some light. Presumably, the proposed explanation of the impossibility of transparent white is intended to apply to paradigm white things. Ergo, it is intended to apply to things that absorb some light, as well as scattering plenty. This is the thin end of a wedge. For if white things are opaque because they scatter lots of light, and absorb some, then opacity is causally linked to both scattering and absorption. It is natural to suppose, then, that if you reduce scattering and increase absorption, the object will stay opaque. This bears out, as highly absorbing media, which we call 'black,' are also opaque.[28] Accordingly, media that scatter a little less light than white, and absorb a little more, also should be opaque. Such objects are classed as light NCS greys. As the right-most filter is nearly completely transparent, it therefore cannot be attributed a light NCS grey.

Premise 5 extends this critique of Exceptionalism from the achromatic to chromatic colours. There is reason to think that if perceived transparencies cannot be attributed NCS greys, they cannot be attributed NCS chromatic colours, either. That is because NCS chromatic colours are characterised as mixtures of hues and greys, thus also involve mixtures of white. Recall that the NCS chromaticness dimension specifies the extent to which a hue is 'veiled' by grey. For example, the light pink circled in Figure 3c has 40% chromaticness, thus 60% grey. This grey, in turn, contains 90% white, 10% black. Overall, then, the colour contains 54% white. For the reasons discussed above, however, the perceived colours of transparencies cannot contain any significant amount of white. Accordingly, perceived transparencies cannot be attributed colours such as this NCS pink.

To illustrate, consider the lemonade and glass in Figure 6. The perceived colour of the lemonade seems close to the NCS pink. As expected, the colour seems to contain a fair proportion of white. The lemonade appears a little translucent, almost totally opaque. This is also as expected, given the association between white, scattering, and opacity. Now, the glass is also described as light pink, yet it looks highly transparent. Its perceived colour therefore cannot be characterised as containing any significant proportion of white. The glass is attributed some other colour: call it *transparent pink*. This shows how, finally, to resolve my interior design problem. Although we call both the paint and

[28] I develop this point in Section 3. It is pre-empted by Wittgenstein (1977: §I.21), quoted above, who says that 'both white and black are opaque or solid.' [BLINDREF].

bottle 'light green,' they are not attributed the same colours. The paint is attributed a colour that is light by dint of containing lots of white. The bottle, though, cannot be attributed a colour containing lots of white, as then it would appear opaque. The bottle is attributed some other colour: a *transparent light green*. That concludes the argument for Uncommon Colours.

Figure 6. (a) pink lemonade, (b) pink glass.

3. Clear Colours

Uncommon Colours raises an important question, as to how to characterise the perceived colours of transparencies, if not in terms of mixtures of black and white. My answer is *Clear Colours*: these perceived colours can be characterised by an achromatic dimension ranging from black to clear, or perfectly transparent.[29] Colours lying along this dimension can be characterised as mixtures of black and clear, which yield *transparent greys*. These differ from the NCS greys, which involve mixtures of black and white. Chromatic transparent colours can be characterised as mixtures of hues and transparent greys. Transparent pink, for instance, can be characterised as a mixture of a reddish hue, and a transparent grey that is closer to clear than black.

In one sense, Clear Colours is the obvious answer, suggested by a naïve description of the series of achromatic transparencies in Figure 5a. Intuitively, this series starts at black, and approaches perfect clarity. Clarity thus stands to black in this transparent series, as white stands to black in the opaque series. All can agree on this much. As we have seen, however, philosophers generally have

[29] Averill (1992: 566) suggests a different answer: 'objects that… transmit light are not white, black, or grey, but more or less bright.' This is confused, as 'brightness' conventionally denotes an intensive, achromatic dimension of unrelated colours, ranging from dim to dazzling. This is apt to characterise the appearance of objects perceived in the aperture mode, which appear self-luminous; but transparencies do not (usually) appear self-luminous. The limit of a series of achromatic transparencies is not dazzling, but clear.

not inferred correspondingly different perceptual continua. The consensus has been Exceptionalism, on which perceived transparencies and opacities can be attributed the same colours, except for white. Clear Colours is unorthodox, then, in claiming that black-clear is an achromatic dimension of perceived colour, distinct from the black-white dimension.

Clear Colours holds that clear is a limit achromatic colour. This is also unconventional, as clear is generally not considered a colour quality. Indeed, many hold that clear is not even a perceptible quality, on the grounds that paradigm clear things are invisible. As Buckner (1986: 86-87) puts it,

> what characterizes water, window-panes and the air is the complete absence of any identifiable visual quale: they are "colourless" in the sense that they have neither chromatic nor achromatic colour… Achromatic transparency is, if you like, a visual zero: the absence of any visual quale whatsoever.

Hardin (1985: 118) likewise holds that a clear mirror

> carries no visible marks of its character, for it alters only the direction of the light incident upon it. It is thus uncoloured, just as a loudspeaker is said to be uncoloured if it does not noticeably add to or subtract from the structure of its input…

Similarly, a clear transparency leaves no 'visible marks' on the light passing through it, hence is invisible. Given that colours are visibilia, if anything,[30] clear objects are deemed completely colourless.

I now argue for Clear Colours in three steps. First, I argue that clear is a perceptible quality, not a mere 'visual zero.' Second, I argue that clear is, specifically, a colour quality. Third, I provide some clarifications, and respond to an objection.

Buckner is right that clear things are often invisible. Many, though, are clearly visible. Water is a prime example, as are diamonds, ice, cling film, and Perspex. We even see air, in the form of

[30] I paraphrase Strawson's (1973: 109) famous dictum.

bubbles in liquid or glass.[31] I take it nobody denies that these can be objects of perception. This still leaves room for disagreement, though, as to whether such perceived objects are positively perceptually characterised as clear. Take the ice cubes in Figure 7b. Someone might claim that we see the cubes, but only those parts where there are surface reflections. The other parts remain invisible, and are perceptually attributed no features whatsoever. Call this *Visible Parts*. Mizrahi (2018: 243-244) defends this view,[32]

> An object can then be partially visible and invisible depending on what region of the object is perceived…. [W]hen its surface, or part of it, becomes visible, it partially or totally loses its transparency. In that case, the object, or a part of it, ceases to be a visual medium and becomes the direct object of perception.

On Visible Parts, then, although we do see some parts of the cubes, these parts appear opaque, as their surface reflections obscure things behind. No visible parts of the cubes appear clear, consistent with clear not being a perceptible quality.

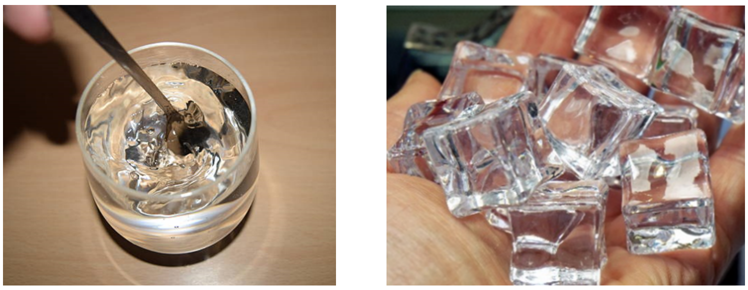

Figure 7. (a) stirring water, (b) ice cubes.

Visible Parts conflicts with both the phenomenology and visual processing underlying such experiences. Phenomenologically, it does not seem as though one sees scattered, disconnected parts of ice. One sees several cubes, bound by continuous and connected surfaces. The reflections help in discerning these forms, just as shading provides a sense of contour. But the reflections do not appear as fragments in empty space: they appear to lie on a solid, material surface that screens the light, and

[31] Perhaps portions of atmospheric air can be discriminated, as with heat haze, where hot air near the ground causes refraction and shimmering distortions.
[32] [BLINDREF].

thus determines the orientation of the plane where the reflections appear. This is particularly evident in dynamic cases. Imagine rotating one of the cubes, so it reflects light at different points. Visible Parts predicts that one should see a succession of scattered parts, continuously changing as the cube rotates. On the contrary, one sees reflections in continuous motion across an icy plane, like ripples propagating across the surface of a pond. The whole surface manifests in experience, as that which unifies and situates the illumination-dependent changes in appearance.

As for visual processing, much early- to mid-level processing is geared towards 'contour-' and 'surface-integration.'[33] These processes function to detect the presence of unified or continuous edges and surfaces in the scene. They begin operating on features registered in the visual image, which are often spatially discontinuous, and link these into coherent wholes. The processes exploit cues that predict the presence of a unified environmental edge, like good continuation, smooth curvature, consistent contrast magnitude and polarity, and so forth. Surface integration exploits contour-related cues like closure and ownership, along with cues to consistent colour, texture, and motion.[34]

Now, Visible Parts predicts that these processes play little to no role in visual experiences of ice cubes, water droplets, diamonds, and such like. For it holds that we only see the parts of clear transparencies that reflect light, not the connecting, non-reflecting parts. In general, though, contour and surface integration processes are heavily implicated in transparency perception, as in all object perception. The neon colour spreading illusion in Figure 8 gives a striking illustration. The image appears to show a transparent blue disc, overlaying four sets of black rings. The only actual cues to transparency in the image are the six blue arcs in each set of rings. These arcs produce contour fragments where they connect with the black lines. Although the fragments are spatially discontinuous, their local orientations, and consistent chromatic and luminance contrast and polarity,

[33] On contour integration, see Field et al. (1993), McIlhagga & Mullen (1996), and Machilsen & Wagemans (2011). Burge (2022: 82-90) and Lande (2023: §4.2) provide philosophical discussion. Seminal work on the relationship between contour, depth, and transparency include Adelson & Anandan (1990), Anderson (1997), and Nakayama et al. (1990). On surface integration, see Nakayama et al. (1995), Yin et al. (1997, 2000), and Su et al. (2010).
[34] Qiu & von der Heydt (2007) present evidence that neurons in macaque V2 assign border ownership consistent with percepts of transparency. [BLINDREF].

predict a continuous environmental edge of constant curvature. The visual system evidently runs with this prediction, forming a representation as of a circular contour. This closed contour, along with the uniform blue colour of the arcs, predicts a continuous environmental surface, which is duly 'filled-in' by surface integration processes.[35]

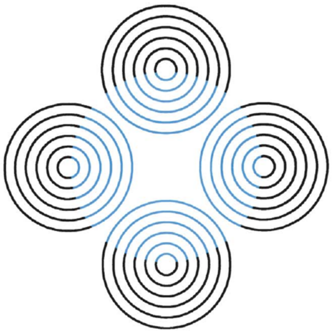

Figure 8. Neon colour spreading. Source: Pinna & Grossberg (2005).

Returning to the ice cubes, the image contains a complex web of contour fragments; some produced by reflections on the outward-facing surfaces, but also by internal reflections, and refraction maxima towards the edges of the cubes. These fragments provide strong cues to the presence of environmental edges and surfaces. Given the demonstrable role of contour- and surface-integration in producing percepts of transparent objects, it is likely that these processes operate in these clear contexts too. This conjecture is not just empirically plausible, but phenomenologically motivated, given the preceding points.

Contra Visible Parts, then, some clear parts of the ice cubes are seen. It does not immediately follow, though, that these perceived parts are attributed the feature, *clear*. I establish this further point, by arguing that we have approximate perceptual constancy for material clarity, or *clarity constancy*, across changes in illumination, background, and through mechanical deformation.[36]

[35] Other cues involved in transparency perception include global statistics of means and standard deviations of cone excitations (Faul & Ekroll, 2002, 2011; Khang & Zaidi, 2002a,b; Ennis & Doerschner, 2021); stereo disparity (Falkenberg & Faul, 2019); optical distortions due to refraction (Schlüter & Faul, 2016), and locally unbalanced motion cues, signalling so-called 'transparent motion,' (Qian & Anderson, 1994).
[36] I assume that if subjects have approximate constancy with respect to clear, then they perceptually attribute that feature. On this connection, see Burge (2022: 64-105).

Imagine rotating an ice cube, varying the illumination of its surfaces. Throughout these changes, the surfaces appear roughly invariant in some of their intrinsic material qualities. For instance, the surfaces appear fairly uniformly glossy. This glossiness manifests in the systematic way in which the surfaces interact with the illumination, as they change their orientations to the light source. Glossiness, after all, involves dispositions to specularly reflect light. Yet the glossiness itself appears as a relatively stable feature of the material surface, not the illumination it reflects. Empirical studies confirm this point, indicating that subjects have reasonable *gloss constancy* across variations in illumination.[37] I contend that the surfaces also appear fairly uniformly clear.[38] Like glossiness, this clarity manifests in the systematic way the surfaces interact with the illumination. As Broackes (1992: 459) observes in connection with surface colour constancy, 'there is a constant *relation* between incident and reflected [and transmitted] light: there is a constant *way in which the surface changes the incident light.*' Firstly, although the surfaces appear to reflect light in different places, they only ever seem to reflect light specularly. These reflections always preserve the spatial structure of the illumination, and do not scatter or diffuse it. Secondly, these specular reflections appear spectrally unbiased, perfectly mirroring the colour of the illumination. Thirdly, the shadows cast by the cube also appear spectrally unbiased, and noticeably brighter than those formed by more absorbent media.

To illustrate, take the glass objects in Figure 9. These are presented under the same, slightly bluish illumination. All three have highlights on their surfaces, and cast shadows on the background. The colours of the highlights and shadows formed by the red and green glass are visibly skewed towards red and green. This is because the light they reflect and transmit is filtered by spectrally selective absorption.[39] In contrast, the highlights and shadows produced by the clear glass appear spectrally unbiased. These shadows are also noticeably brighter than those of the red and green glass. The glass affects illumination in this distinctive way, because it is spectrally unselective and

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[37] Fleming et al. (2003) and Dror et al.(2004) provide psychophysical evidence for such illumination-independent gloss constancy, though Olkkonen & Brainard (2010) report limitations. See also Chadwick & Kentridge (2015: 225-227) on the role of illumination cues in gloss perception.
[38] For psychophysical studies of clarity constancy, see Gerbino et al. (1990), Khang & Zaidi (2002a,b), Ennis & Doerschner (2021).
[39] To clarify, the total specular reflection from a transparent filter depends on its absorption and scattering characteristics, as well as its reflectivity. Specularly reflected light does not simply 'bounce off' the surface: it is filtered by the medium. For details, see Nakauchi et al. (1999: 2614).

minimally absorptive; in other words, because it is clear. This clarity manifests visually in the ways the glass affects the illumination.

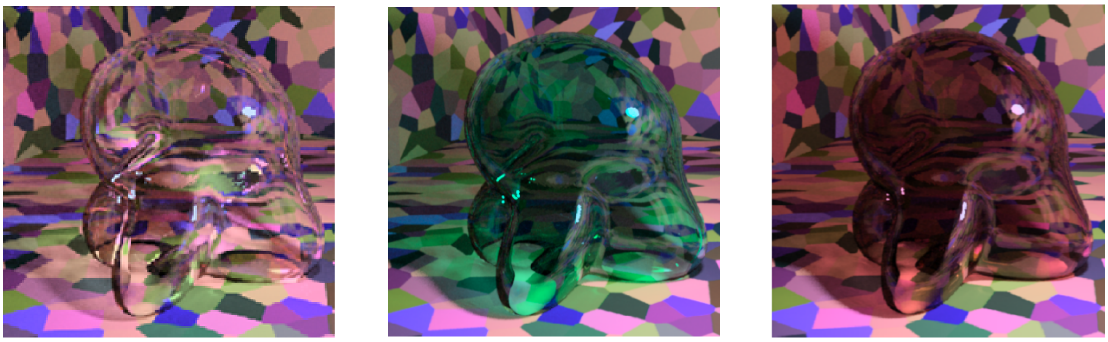

Figure 9. Glass transparencies with highlights and shadows. Source: Ennis & Doerschner (2021).

We also have approximate clarity constancy across background variations.[40] Imagine tracking the ice cube as it moves around the room, over a pinkish hand, some blue wallpaper, a green rug, and so on. The perceived scene changes continuously in its overall appearance. Nonetheless, the cube appears invariantly clear. This clarity manifests partly in the consistent ways the cube affects the appearance of the background. Firstly, the cube distorts the shapes and sizes of things behind in a consistent, predictable way. These distortions evince the constant refractive properties of its surfaces, with refraction minima at the centres, and maxima near the edges. Secondly, while the cube visibly distorts the background, it does not appear to darken or colour it, as would green or red glass. Thirdly, the cube does not significantly reduce the contrast of things behind. As above, the ice affects the background in this way because it is spectrally unselective and minimally absorptive; in other words, because it is clear.

We also have approximate clarity constancy across mechanical deformations. Imagine stirring some water with a spoon, as in Figure 7b, so the liquid deforms into a swirl. The interior parts of the water appear in motion, relative to the static reference frame of the glass. Unlike still water, these parts distort the image of things behind in irregular ways. In fact, the swirl is barely see-through. Yet

[40] Faul & Ekroll (2002) and Robilotto & Zaidi (2004) present psychophysical evidence for approximate background-independent clarity constancy. For discussion of image distortion cues in transparency perception, see Fleming et al. (2011), Chen & Allison (2013), and Schlüter & Faul (2016). The arguments of this paragraph and the next bear some similarities to Mac Cumhaill's (2015: 697ff) argument that we perceive empty space.

the liquid does not appear to lose its intrinsic, clear quality. Firstly, as above, the highlights formed by the swirl are spectrally unbiased. This includes highlights visible inside the swirl, on internal surfaces induced by the deformation. Secondly, its shadows do not significantly darken or colour things beneath. Thirdly, the interior parts of the swirl are highly visible, unlike the parts of a whirl of turbid water. The unifying explanation again is that the water is spectrally unselective and minimally absorptive; in other words, it is clear.

I have argued that objects appear approximately constantly clear, across variations in illumination, background, and through mechanical deformation. In this sense, appearing clear involves a positive perceptual character, not a mere visual zero. I believe this is overlooked, as people tend to assimilate appearing clear to being completely see-through. As these cases show, however, things like swirling water can appear clear, despite being barely see-through. These features also dissociate in the other direction: the air is see-through, but does not appear clear, in the way water, ice, diamonds, and bubbles appear clear. Appearing clear and being see-through are thus different notions. 'See-through' is a relational, functional notion: something is see-through, just in case other things can be seen-through it. Being see-through is not a perceptible quality of the object seen-through.[41] On the present view, in contrast, 'clear' denotes a perceptible quality, a feature attributed to objects in visual perception. Clear is thus a way that transparent objects can appear.

I have been arguing that clear is a perceptible quality. Clear Colours says something stronger: that clear is a colour quality. This entails that being clear is a way of being coloured; also, that appearing clear is a way of appearing coloured.[42] I now argue for Clear Colours, by appealing to the optics of transparency. Until now, we have treated transparency-opacity as an intuitive, linear scale, ranging from see-through to not-see-through. In optics, transparency-opacity is measured by the *attenuation coefficient*, which measures the extent to which a beam is weakened as it passes through something.[43] This too forms a linear scale, ranging from zero to infinity, though in practice it is

[41] This is contra Brown (2014: 2), who claims that 'to experience something as transparent is most fundamentally to be in a visual state that represents that thing as something through which one can see.'
[42] [BLINDREF].
[43] For details, see Johnsen (2011: 120-122), (who uses 'extinction coefficient'), and Tilley (2011: 34-36). Westphal (1986: 312) and Hardin (1989: 285) define 'transparency' in terms of 'transmittance.' This is apt to

capped at a large, but finite value. This scale, however, compresses two underlying dimensions of variation. For attenuation is defined as the sum of two, more basic magnitudes: absorption and scattering. Intuitively, a beam passing through a medium can be weakened by light being absorbed or scattered. The more it is weakened, the opaquer the medium.

This is schematized in the *transparency-opacity manifold* in Figure 10. The top vertex represents the attenuation minimum, or transparency maximum, where scattering and absorption are at zero. Call this *optically pure clarity*. The other vertices represent two attenuation maxima: one for maximal absorption, or *optically pure black*, the other for maximal scattering, or *optically pure white*. I call these 'optically pure,' as the vertices represent optical magnitudes, not sensible qualities. The *clear-black line* represents the path from minimal attenuation to maximal absorption, holding scattering at zero. The *clear-white line* represents the path from minimal attenuation to maximal scattering, holding absorption at zero. The *black-white line* connects all points of maximum attenuation, hence maximum opacity. It represents the path from maximal absorption to maximal scattering, via varying proportions of the two.

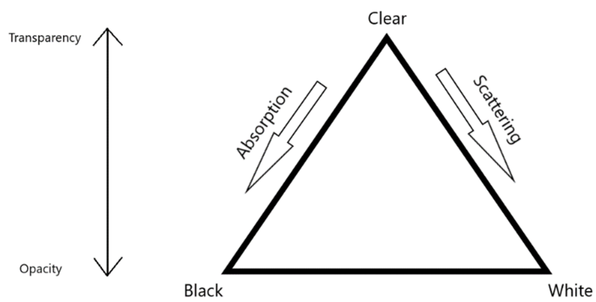

Figure 10. Transparency-Opacity Manifold

I now develop six points concerning this manifold, which build a case for Clear Colours. Firstly, when we decompress the attenuation scale, we get a two-dimensional space, which contains a black-white line within it. This line represents optical magnitudes, not sensible qualities. Nevertheless, it is notable that an optical black-white continuum should emerge as part of the

mislead, as 'transmittance' is often used to denote specular transmittance, which involves no scattering, and depends only on absorption. (Similarly, 'reflectance' canonically denotes diffuse reflectance.) In general, though, opacity – and hence its dual, transparency – depends on both scattering and absorption.

transparency-opacity manifold. Optically pure black and white lie at the limits of this line, which represent maximum absorption and scattering, respectively. From this perspective, then, optically pure black and white are just maximal and simple types of opacity. Maximal, in the sense of maximally attenuating; simple, in the sense of involving only absorption, or scattering, not both. All other points on the black-white line represent maximal but complex types of opacity, involving both absorption and scattering.

Secondly, all points on the black-white line are connected to the attenuation minimum, or optically pure clarity. Optically pure black and white are connected to it along the black-clear and white-clear lines, respectively. The mid-point of the black-white line is connected to it by a line that bisects the manifold, representing balanced proportions of absorption and scattering; and so forth. On this manifold representation, then, optically pure black and white, and all points in between, are continuous with transparency.

Thirdly, the black-white line is causally and structurally related to the NCS achromatic continuum. As for causal relations, the NCS colour, white, is causally linked to scattering. A pure NCS white object would map to the scattering maximum in the manifold. NCS black is causally linked to absorption. A pure black object would map to the absorption maximum in the manifold. As argued above, NCS greys can be characterised as mixtures of white and black, so plausibly involve both scattering and absorption. NCS grey objects thus map to intermediate points on the black-white line. As for structural relations, the black-white line is homomorphic to the NCS achromatic continuum. That is, there is a mapping between these structures that preserves the linear order of points on each scale.[44] Starting at maximal absorption, increasing scattering takes you monotonically from optically pure black to optically pure white. Similarly, starting at NCS pure black, increasing whiteness takes you monotonically to pure white.

[44] Homomorphism allows that the colour continuum may not be dense, for instance, whereas the optical continuum presumably is dense. Also note that the mapping will be nonlinear, reflecting psychophysical laws such as Weber's or Fechner's law.

Fourthly, granting that clear is a perceptible quality, there is a perceptual continuum from black to clear. As above, the optical black-clear line is causally and structurally related to this perceptual black-clear continuum. A pure black object maps to the absorption maximum. A perfectly clear object would map to the attenuation maximum. Objects that lie somewhere between black and clear, like the grey filters, would map to intermediate points along the black-clear line. As for structural relations, there is another homomorphism, or mapping between these continua that preserves linear order. Starting at maximal absorption, decreasing absorption, while holding scattering at zero, takes you monotonically from optically pure black to optically pure clarity. Similarly, for the perceptible qualities, starting at the black of the first filter, increasing perceived clarity takes you monotonically to clear.

Fifthly, these points undermine Qualitative Independence. I stress that the transparency-opacity manifold is an optical magnitude space, not a quality space. Ex hypothesi, though, there are systematic causal and structural relations between the NCS, a widely adopted psychological colour space, and this optical magnitude space. The NCS achromatic continuum is mirrored by the black-white line, which represents maximal types of opacity. There is a similar correspondence between the perceptual black-clear continuum, and the black-clear line. The manifold thus mirrors the structure of both perceptual continua. The black-white line is continuous with the black-clear line, overlapping at optically pure black. It follows that the perceptual continua are mirrored by structures in optical magnitude space that are, themselves, continuous. This gives reason to think that the NCS achromatic colours are continuous with transparency-opacity qualities. For if they weren't, it would be hard to explain why the transparency-opacity manifold should mirror other aspects of their structure, up to homomorphism, but fail to mirror their discontinuity. Given that the achromatic NCS colours are continuous with the chromatic NCS colours, transparency-opacity qualities are continuous with the NCS colours, simpliciter. Call this *Qualitative Dependence*.

Sixthly, and finally, Qualitative Dependence gives reason to think that clear is a limit achromatic colour. In section one, I assumed that sensible qualities are individuated by their relations of similarity and difference. To be a colour, is to be similarity related to other colours. Now, grant that the quality, clear, is continuous with the colours. Contrary to initial impressions, this means it is legitimate to ask whether some perceived grey quality is more similar to clear than white, or more similar to black than clear. As a reality-check, consider again the achromatic filters and paints in Figure 5. Reassuringly, these questions seem entirely appropriate here. The perceived colour of the right-most filter does seem more similar to clear than white. The perceived colour of the left-most filter does seem more similar to black than clear. This commensurability suggests that clear is, indeed, a colour.

Consider the following, further point. In the NCS, chromatic colours span out from the achromatic axis, which runs from black to white. If you take an NCS grey of 50 blackness, and increase the chromaticness in the red direction, you get a continuum of increasingly saturated dark NCS reds, as in Figure 3c. If you take an NCS grey of 10 blackness, and increase chromaticness in the red direction, you get a continuum of increasingly saturated light NCS reds, intersecting the pink circled in Figure 3c. Now, take the perceptual black-clear continuum. The chromatic transparent colours span out from this axis, similar to the NCS achromatic axis. If you take a transparent grey of 50% black and 50% clear, and increase chromaticness in the red direction, you get a continuum of increasingly saturated dark transparent reds. If you take a grey of 10% black and 90% clear, and increase chromaticness in the red direction, you get a continuum of increasingly saturated light transparent reds, perhaps including the transparent pink of the glass in Figure 6. In this transparent colour space, then, clear stands in the same relative position to black and the chromatic transparent colours, as white stands to black and the chromatic NCS colours. In other words, clear is structurally homologous to white. Given that we take white to be a limit achromatic colour, we should consider clear to be a limit achromatic colour too.

To clarify, I am not claiming that the perceptual black-clear dimension is isomorphic to the NCS black-white dimension. There might be fewer discriminable differences between black and clear, than black and white, for example. I am also not claiming that the transparent chromatic colours are isomorphic to the NCS chromatic colours. There might be fewer discriminable differences between the achromatic and maximally chromatic transparent colours, in some or all directions. The chromatic transparent colours might have a different coordinate structure to the NCS chromatic colours. These are open empirical questions.[45] I do claim that the transparent colours are continuous with the NCS colours, overlapping at black. To help visualise, think of the NCS and transparent colours as two spheres connecting at a point, like an hourglass. This connecting point corresponds to black. There are continuous 'vertical' lines running through both spheres, like unbroken lines of longitude. These lines connect white to clear, via black. One interpretation is that these represent lines of constant hue, running through both the NCS and transparent colours. This allows that the transparent colours can be represented by the same hue dimension as the NCS colours. Starting at white, for instance, you could follow a line of constant pure NCS green through NCS light green, NCS dark green, to black, then onto transparent dark green, transparent light green, and finally, clear. Alternatively, although these lines are continuous, they might be associated with a different coordinate system in each sphere.[46] That means that the transparent colours cannot be represented by the NCS hue dimension. The transparent colours might have hues structurally similar to the NCS, but not strictly NCS hues. Again, these are open empirical issues. The point is that, whatever the structure of the transparent colours, clear is homologous to white, standing to black and the chromatic transparent colours as white stands to black and the chromatic NCS colours. Therefore, clear should be considered an achromatic colour.

Someone might resist this conclusion, by denying that white is a colour. For if white is not a colour, the homology between white and clear gives no reason to think that clear is a colour. Ralph Evans (1974: 87) takes this line, claiming that 'whiteness is *not* a colour variable but… refers to a combination of stimulus physical characteristics that have in common the fact that they are *colourless*.' Evans thinks that all perceived colours can be characterised by an achromatic dimension running from black to colourless, rather than black to white. This follows from a restricted definition of 'perceived colour' as involving 'perceptual attributes that can be changed by changing *only* the energy or the spectral distribution of the light reaching the eye from some part or all of the complex

[45] Faul & Ekroll (2011) and Faul (2017) offer promising insights on the structure of transparent colour space.
[46] Note that, though these lines are strictly continuous, they are not smooth, due to the 'pinch point' at black. The lines are, therefore, not differentiable at that point. If we require hue functions to be everywhere smooth, then the transparent colours must have a different hue function.

stimulus being viewed,' (1974: 88). White is not a 'pure colour perception', because white is associated with scattering and opacity, which are 'object characteristics,' not light characteristics, (1964: 1468). Call this *White Denialism*.

White Denialism resists Clear Colours, but at significant cost. Firstly, it goes against common sense. As Hardin (1988: 25) notes, 'by perception and common speech, Joseph's coat may have had many colours, but the colour of the bride's dress is just one colour, white.'[47] Admittedly, this has little suasive force in the present context, as Clear Colours also violates common sense in deeming clear a colour. Nevertheless, I suspect the folk are more confident that white is a colour, than that clear is not. Given a forced choice, they would take Clear Colours over White Denialism.

Secondly, and more troublingly, White Denialism treats colour as a perceived feature of light, not material objects. Evans (1964: 1468) says that 'light so perceived can have *nothing to do* with objects. Any perception that has to do with an object in any way is not a light-colour perception as here intended.' From a certain technocratic perspective, this makes perfect sense. Light is, of course, the stimulus for (almost) all colour perceptions. At a physiological level, this light excites cones. Any coloured object therefore can be represented in terms of the cone excitations it will produce, in certain specific conditions.[48] This is the idea behind *psychophysical colour spaces*, like the CIE *XYZ* tristimulus space, and reparameterizations of it, such as the CIE *xyY* (the basis for the CIE chromaticity diagram) and *L*a*b** spaces. CIE *XYZ* values, for instance, are derived by integrating the spectral power distribution of the light stimulus, weighted by the CIE 1931 colour matching functions. Effectively, each *XYZ* coordinate represents an infinite set of metameric lights, which match the mixture of spectral primaries represented by that point.

Uncontroversially, transparent and opaque stimulus configurations can have the same CIE *XYZ* values, hence CIE *xyY* and *L*a*b** values. Notoriously, though, the CIE *XYZ* and *xyY* do not represent the colour appearances of such stimuli: they represent sets of metameric lights, not

[47] Cf. Matthen (2020: 167).
[48] In practice, excitation values are predicted for a 'standard observer,' viewing the object under a specific CIE illumination, against a uniform achromatic background, and projecting an image of a certain size to the retina – specifically, subtending two degrees, approximately matching the size of the fovea.

perceived colours. The CIE $L^*a^*b^*$ is more nuanced, as it was intended as a perceptually uniform space for opaque coloured surfaces. Confusingly, its dimensions are sometimes glossed as 'white-black,' 'red-green,' and 'blue-yellow.' While this suggests a perceptual basis, the space is strictly psychophysical. The L^* dimension, for example, is defined by a nonlinear transformation of the tristimulus value *Y*, itself a function of stimulus luminance.[49] For some technical purposes, it is useful to represent transparent stimuli in CIE $L^*a^*b^*$. But we should not confuse technocracy for perceptual theory. Jarringly, an opaque white stimulus maps to the same point in CIE $L^*a^*b^*$, as a stimulus configuration containing a clear filter over a white background.[50] On Evans's conception of 'pure colour perception', these stimuli have the same perceived colours. As argued above, by adopting a certain viewing strategy, one can certainly make the transparent configuration look like an opaque white surface. In doing so, however, one undermines perceptual transparency, thus screening off questions about the perceived colours of transparencies. If one reflects carefully on these questions, along the lines I have described, one should reject White Denialism, and accept Clear Colours.

4. Colour, Space, and Form

In closing, I discuss some broader philosophical implications of the account, along with some empirical predictions. Philosophical orthodoxy largely treats colour perception as homogenous and autonomous. Homogenous, in that colours appear in the same fundamental ways in all perceptions, regardless of the type of object one perceives. Autonomous, in that colour perceptions are explained independently of object perceptions. As Mausfeld (2010: 123) says, the assumption is that the 'core properties [of perceived colour] do not depend on the type of "perceptual object" to which it pertains and… "colour per se" constitutes a natural attribute in the functional architecture of the perceptual system.' This orthodoxy manifests in Common Colours, which holds that perceived opacities and

[49] The L^* dimension is labelled '*L*' for 'lightness.' This term is apt to cause confusion. Often, 'lightness' is used to refer to a presumed white-black dimension of psychological colour space. It is important, though, not to confuse 'lightness' in this sense with 'lightness' in the sense of CIE L^* values.
[50] Ennis & Doerschner (2021: 10, 20, 38) and Faul (2017: 17, 19) discuss further inadequacies of CIE $L^*a^*b^*$ for representing the perceived colours of transparencies.

transparencies are attributed the same colours. The present account challenges this orthodoxy, undermining both autonomy and homogeneity.

Against homogeneity, Uncommon Colours holds that colours appear in different ways, depending on whether they appear as features of opaque objects, or transparent objects. Clear Colours holds that in the latter case, colours appear to vary along the dimension of black-clear, rather than black-white. Against autonomy, the arguments for Clear Colours, in particular, evince deep explanatory interdependencies between colour perception, and the perception of transparent objects. The argument against Visible Parts showed that transparent colour perception must be explained in the context of transparent object detection, which involves processes of contour and surface integration. The arguments for clarity constancy highlighted further connections to the perceived illumination, refracting properties, and mechanical deformation of transparent media. The argument that clear is a colour connected the structure of perceived colour, to the latent structure of the optical magnitudes underlying material transparency-opacity. The account of transparent colour perception interfaces with explanations of transparent object perception at each turn.

In these respects, the account refines insights from the Gestalt psychology. Koffka (1936b: 129) claimed that 'a general theory of colour must at the same time be a general theory of space and form.' Katz (1911/1935: 2) elaborated as follows,

> Inasmuch as space is always presented in coloured form, it plays an important part in determining the colour-impressions which we receive. Without the spatial factor we should lack the wealth of spatially organized modes of appearance which colours assume, and inasmuch as colour is always presented in spatial form it exercises a corresponding influence on the impression of space.

Transparency is a case in point. Transparency perception involves 'scissioning' the visual image, representing a transparent object as apart from its background, lying in a nearer depth plane. Transparency perception thus implicates depth perception, alongside contour and surface integration. Katz's point is that this distinctive 'spatial factor' is part of the explanation for the transparency mode of colour appearance. Wittgenstein (1977: III.142) seemed to grasp this point, noting that 'the various "colours" do not all have the same connexion with three-dimensional vision.' He nevertheless resisted the idea that 'there are transparent and opaque colours,' (1977: III.76). On the present account, in contrast, transparent colours involve a sui generis achromatic dimension, running from black to clear. Like all colours of objects, clear manifests in the constant ways that clear media change the light. This includes not just effects on incident light, like highlights and blockages or shadows, but also light reflected from things behind. This shows Katz's 'spatial factor' in action; for unless one sees where the transparency is located, and how it is shaped and oriented, there is no way of seeing how it affects light from above and below.

The account generates many scientifically testable predictions. For example, Uncommon Colours predicts that colour perceptions associated with opaque and transparent objects will have different neural signatures. Although rarely studied, at least one study supports this contention. An fMRI study by Dojat and colleagues (2006: 363) found that

> the neural areas activated by transparency are separable from those areas differentially activated when subjects view colour patterns *versus* the same achromatic patterns. Thus, our study suggests that the integration of local colour differences to signal a transparent layer in an image involves a stage at which coding of the stimulus is being transformed into a representation of an object.

Transparent stimuli particularly activated the anterior parahippocampal gyrus, an area also implicated in perceiving naturally coloured objects, as compared with artificial stimuli. These are fascinating issues, meriting further scientific and philosophical attention.

Clear Colours predicts that perceptions of clear should have a distinctive neural signature, distinguishable from the signatures associated with opaque colours perceived in the background, and functionally continuous with signatures associated with perceptions of achromatic colours between clear and black. It also predicts that there should be perceptual contrast and adaptation effects for clear, much as for white and black.[51] For example, a transparent mid-grey filter bordered by a visibly clear filter should appear darker than when bordered by dark grey filter. Similarly, if one adapts to a clear filter, a mid-grey filter should look darker than when one has adapted to a dark grey filter. To my knowledge, there is little existing work on such issues. No doubt, this is partly due to the technical challenges of isolating the perceptual effects of clear stimuli, as apart from their backgrounds. The advent of realistic simulations of curved transparent objects, as in Ennis & Doerschner (2021; see Figure 9), should facilitate such work. I welcome the results.

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