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What is it like to be colour-blind? A case study in experimental philosophy of experience

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What is the experience of someone who is "colour-blind" like? This paper presents the results of a study that uses qualitative research methods to better understand the lived experience of colour blindness. Participants were asked to describe their experiences of a variety of coloured stimuli, both with and without EnChroma glasses—glasses which, the manufacturers claim, enhance the experience of people with common forms of colour blindness. More generally, the paper provides a case study in the nascent field of experimental philosophy of experience.

KEYWORDS
colour, colour blindness, EnChroma, experimental philosophy (x-phi), perception, qualitative methods

1 | INTRODUCTION

1.1 | What is it like to be colour-blind?

What is the experience of someone who is colour-blind like? The *standard view* of colour blindness, and the view that the colloquial name "colour blindness" suggests, is that someone who is (e.g.,) red/green colour-blind is unable to see reds and greens—they are *blind to* these colours. As Palmer puts it in his authoritative textbook on vision science, these perceivers:

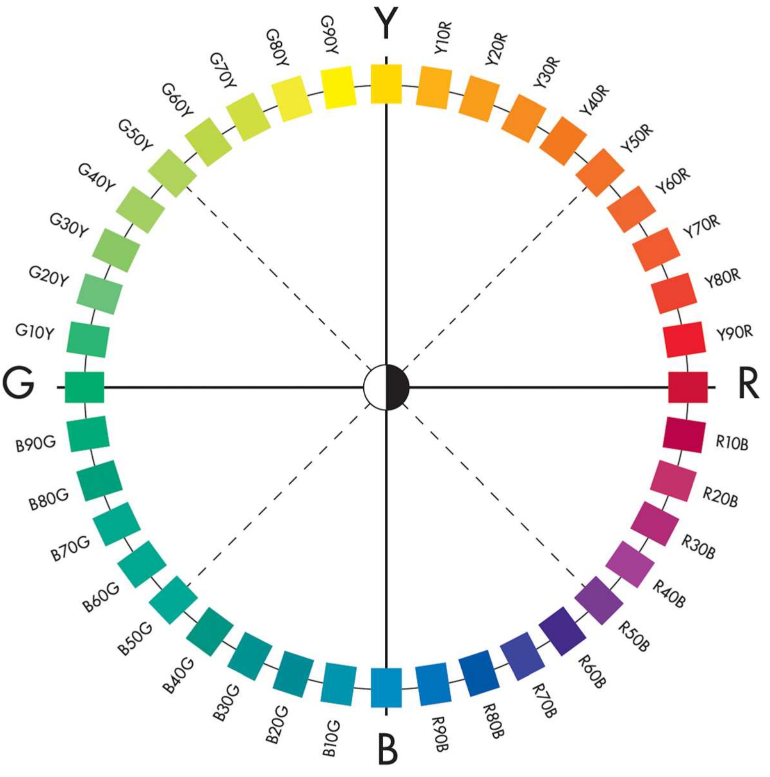


FIGURE 1 Natural Colour System (NCS) colour circle. The circle shows a progression from yellow (Y) to red (R) to blue (B) to green (G) and back to yellow in 10% steps. Elementary hues are located at the cardinal compass points, binary hues are designated in terms of their degree of visual resemblance to elementary hues. Reproduced by permission of NCS Colour AB, Stockholm 2021

> fail to experience red and green hues, both of which are presumably seen as grays. As a result, the world appears to them in various shades of blues, yellows, and grays, as though the red/green dimension of the color solid has been eliminated (Palmer, 1999, p. 104).

If you imagine someone who is red/green colour-blind looking at the *natural colour system* (NCS) colour circle (Figure 1), the standard view predicts that the elementary hues at due east (red) and due west (green) should look grey. There will, presumably, also be effects on the "binary hues" that are "phenomenally composed" of red and green, represented on the NCS colour circle as lying between the cardinal compass points to reflect their binary nature: These include orange (reddish-yellow), purple (reddish-blue), turquoise (bluish-greenish) and lime green (greenish-yellow).[1]

This view of the experience of colour blindness, or "colour vision deficiency" (CVD), fits well with textbook accounts of the opponent processing mechanisms underlying colour vision. Red/green colour blindness, the most common form of colour blindness, comes in two varieties depending on which of the retinal receptor types (L, M or S) are lacking: In *protans* it is L cones, in *deutans* it is M cones. At the same time, perceivers who are red/green colour-blind also differ in the "dimensionality" of their vision. *Dichromats* (*protanopes* and *deutanopes*) only have two functioning retinal receptor types, and as such can match any given coloured light with a mixture of two others. Like "normal" trichromatic perceivers, *anomalous trichromats*

[1] The elementary/binary distinction is due to Hering (1920), whose work served as the basis for the NCS (Sivik, 1997).

(*deuteranomalous* or *protanomalous* perceivers) have three retinal receptor types, but tend to make similar mistakes to corresponding forms of dichromat due to differences in the spectral sensitivity of one of their receptor types.[2]

According to opponent process theories of human colour vision, experience is determined by the outputs of two opponent channels, red-green and blue-yellow, plus an achromatic white-black channel. In "normal" trichromatic perceivers, the inputs to these channels in turn depend on differences in the responses of their three types of retinal receptors. Assuming that someone who is colour-blind lacks one of the relevant retinal receptor types, and as a result one of the opponent channels, it might seem to follow that their colour experiences will be limited to those experiences that can be generated by the remaining chromatic channel and the achromatic channel.

However, does this standard view really capture what it is like to be colour-blind? Despite its widespread acceptance, it has long been known that there are problems with the standard view (e.g., Broackes, 2010, pp. 294–296; Byrne & Hilbert, 2010, pp. 270–274), and a number of competing accounts of the phenomenology of colour blindness exist.

At one extreme, there is the view that colour-blind perceivers in fact perceive *none* of the same colours as normal trichromatic perceivers. Whereas the standard view asserts that people who are colour-blind perceive a only a sub-region of the colour space of ordinary trichromatic perceivers, the *alien colour view* denies that people who are colour-blind see even blue, yellow, grey, white or black. On this view, the colours that colour-blind perceivers see cannot be located in trichromatic human colour space at all.[3]

Intermediate between the standard and alien colour views, Byrne and Hilbert's (2010) *revised reduction/revised alien view* holds that there is both commonality, and radical difference with the experience of normal trichromatic perceivers. According to Byrne and Hilbert, colour-blind and normal trichromatic perceivers have the same experiences of achromatic colours (white, black and grey) and unique yellow and unique blue. In this respect, they agree with the standard view. However, like the alien colour view, they argue that people who are colour-blind perceive colours that normal trichromatic perceivers never perceive. This is because they perceive binary hues as being simply yellowish or bluish (to different degrees):

> [N]ormal trichromats never see this hue [yellowish or bluish] without seeing more determinate hues like orange and yellow. On the Revised Reduction View, a red-green dichromat sees yellowishness unaccompanied. (Byrne & Hilbert, 2010, p. 280).

At the other extreme, the *common colour view* maintains that colour-blind perceivers do not differ from normal trichromatic perceivers as radically as they are often thought to. On this view, colour-blind perceivers are genuinely able to perceive the colours that they are supposedly "blind to," at least in favourable conditions. The ability of colour-blind perceivers to perceive these colours depends in part on the type of stimulus and the way it is presented: Perception of reds and

[2]The received view is that anomalous trichromats have two varieties of one of the receptor types present in "normal" trichromatic perceivers (either M or L), each with slightly different spectral sensitivities (see Bosten, 2019 for a review). Colour blindness affects around 8% of the male population and around 0.5% of the female population in European populations. Deuteranomaly is the most common form of colour blindness, affecting around 5% of the population, while protanomaly, protanopia and deuteranopia each have incidence rates of around 1%. Less common still, with incidence rates of less than 1%, are forms of yellow/blue colour blindness (tritan defects) and achromatopsia, which involves a more complete form of (chromatic) colour blindness (Simonuvic, 2010).

[3]See Hacker (1987). Similar suggestions are made in the case of monochromats by Akins (2014) and other species by Allen (2016).

greens is improved if the stimulus is a material object rather than a spectral light, if the object is well-illuminated, if the stimulus (object or light) occupies a sufficiently large area in the visual field, or is presented for a sufficient length of time (e.g., Broackes, 2010; Merleau-Ponty, 1945, p. 500n19, citing Stein, 1928; Scheibner & Boynton, 1968; Wachtler, Dohrmann, & Hertel, 2004). For instance, Smith and Pokorny (1977) found that dichromats tend to perform more like some form of trichromat when the stimulus occupies more than 8° of the visual field. Similarly, although colour-blind perceivers are generally less accurate at naming colours than normal trichromatic perceivers, they are nevertheless surprisingly proficient, and their performance improves if stimulus presentation time is increased or if stimuli are relatively large (e.g., Cole, Lian, Sharpe, & Lakkis, 2006; Jameson & Hurvich, 1978; Montag, 1994). While different explanations of this proficiency are possible (see Section 4.1), a straightforward explanation is that colour-blind perceivers are genuinely able to perceive the colours of things in a relevantly similar way to their normal trichromatic counterparts, at least in favourable conditions.

The common colour view comes in weaker or stronger forms, depending on whether the experiences of colour-blind perceivers can, in favourable circumstances, match *exactly* those of normal trichromatic perceivers, or whether their experiences are just relevantly similar: For instance, reds and greens might appear to be elementary hues, instances of which are unique (i.e., neither yellowish nor blueish), but appear to CVD perceivers to be darker or lighter and as having a lower degree of "chromaticness," which in the NCS refers to the strength or intensity of a colour, and corresponds to the dimension of Chroma in the Munsell system (Sivik, 1997). Indeed, there may be differences between individuals in this respect, depending on the nature and the extent of their colour blindness. However, whether their experiences are the same or just relevantly similar to normal trichromatic perceivers, the common colour view differs from the standard view in maintaining that colour-blind perceivers can genuinely perceive instances of the colours that are supposedly unavailable to them.

When the conditions are less favourable, colour-blind perceivers will often be unable to discriminate colours that would be discriminable to a normal trichromatic perceiver. It is tempting to think that, in these circumstances, the indiscriminable colours will look to be determinately the same—as on the standard view, for instance, according to which a red apple and a green apple might both look to be an identical shade of grey. However, in his defence of the common colour view, Broackes (2010), himself protanomalous, argues that when the circumstances are less favourable, experiences of CVD perceivers sometimes involve a kind of *indeterminacy* in the way that colours are presented, which can resolve upon further exposure to the stimulus. As Broackes puts it:

> *Looking reddish yellow* is different from *looking greenish yellow*: and both are also different from *looking a dark but desaturated unique yellow*—and the present indeterminate experience is identical with none of them. (Broackes, 2010, p. 364).

1.2 | Aims of the present study

The current study has three aims. The primary aim is to use qualitative research methods to better understand the lived experience of colour blindness, and to try to adjudicate between these competing accounts of the phenomenology. Specifically, we seek to better understand what it is like to be red/green colour-blind by interviewing colour-blind participants about their experience of a variety of coloured stimuli, both with and without EnChroma glasses.

The manufacturers of EnChroma glasses claim that they are able to "improve the lives of people with color deficiency around the world … [providing] … bright, vibrant color for all."[4] If these glasses are effective at enhancing the experiences of colour-blind perceivers, then the expectation is that participants will be able to describe before-after differences in their experience. In this respect, the study provides an implementation of "the method of phenomenal contrast," which seeks to better understand one type of experience by comparing it with another (e.g., Siegel, 2010).[5]

Since there is a question about whether EnChroma glasses *are* effective, one of the subsidiary aims of the study is to use qualitative research methods to investigate EnChroma glasses from a phenomenological perspective. Videos posted online show emotional reactions when people try EnChroma glasses for the first time, and marketing materials on the EnChroma website suggest that the glasses enable people who are colour-blind to perceive the full gamut of colours: "I put on the glasses. Unbelievable! It was suddenly a complete rainbow … These glasses really do work."[6] At the same time, a number of existing psychophysical studies raise serious concerns about whether the glasses are, or indeed could be, effective (e.g., Gómez-Robledo et al., 2018; Mastey et al., 2016).[7]

A third aim is methodological: to assess the prospects of using qualitative research methods in experimental philosophy (x-phi), and more specifically in the nascent field of "experimental philosophy of experience." Recent years have seen the sustained development of x-phi, a research programme that employs methods from the behavioural and social sciences to investigate empirically how we think about philosophically important concepts, with a view to addressing core philosophical questions. However, while there has been some experimental work considering issues in the philosophy of perception (e.g., Fischer et al., 2020; Roberts et al., 2021), and the philosophy of conscious experience more generally (e.g., Reuter & Sytsma, 2020), these areas of philosophical inquiry have been relatively neglected by experimental philosophers.

Why is this? One explanation is that the methods often employed in x-phi cannot get the same traction in this area as they do in other areas of philosophy. A large part of the existing work in x-phi has focused on investigating intuitions about thought experiments, canonical examples of which include Gettier cases and trolley problems. These thought experiments typically involve making judgements about whether certain concepts apply in hypothetical cases. Although thought experiments have a role in philosophical discussions of perception and experience, part of the "data" for philosophical theorising about experience concerns the phenomenological character of experience, or "what is it is like." Methods that are well suited to investigate the types of

[4]https://enchroma.com/pages/about-us (accessed March 2, 2020). As Gómez-Robledo, Valero, Huertas, Domingo, and Hernández-Andrés (2018) note, the strength of the claims made on the EnChroma website have varied over time.

[5]A different way of implementing this method would be to study perceivers who are colour-blind in just one eye. However, these cases are very rare, and existing reports raise significant interpretative challenges; there are also methodological problems, given that the experiences these perceivers have with their dichromatic eye might be affected by the presence of a normal eye. For discussion, see Broackes (2010, pp. 320–333).

[6]https://enchroma.com/ (accessed February 26, 2020).

[7]The present study uses EnChroma glasses to try to better understand the lived experience of colour experience, while simultaneously evaluating the effectiveness of these glasses themselves. A concern might be raised that a single study cannot do both these things: that to use the glasses to decide between competing accounts of colour blindness we need to presuppose that the glasses are indeed effective. However, the approach employed here can be thought of as comparable to that used to solve a simultaneous equation. The two aims of the study can be met if it is possible to formulate a coherent account of the nature of this experience and their effects on it. Independent purchase on the question can also be provided by evidence from previous studies, as well as parts of the present study that do not make use of the glasses.

conceptual judgements people are disposed to make about hypothetical cases may not be equally effective when it comes to better understanding the phenomenological character of experience.[8]

When investigating intuitions about thought experiments, experimental philosophers often use questionnaire-based research methods (although contrast, e.g., Francis et al., 2017). However, questionnaires are not the only research method used in the behavioural and social sciences. Qualitative research methods, such as semi-structured interviews, are also widely used, and might seem better suited to investigate the phenomenological character of experience given that they can provide a much richer, person-centred, source of data. The use of qualitative methods in x-phi is not unprecedented, and similar methods are sometimes used for related purposes in the phenomenological tradition. However, to date qualitative methods have not been widely used by researchers working in x-phi (Andow, 2016). There are likely to be various reasons for this, but in part, this may reflect a "resistance" to the use of qualitative methods within some areas of psychology itself (Jackson, 2015). The third aim of the current paper is therefore to investigate, through a detailed case study, the extent to which qualitative research methods can help us to better understand the phenomenological character of experience.[9]

2 | METHODS

17 colour-blind participants were interviewed (16 males, 1 female, average age 38.5). This sample size was sufficient to reach "saturation," the point at which additional participants repeated responses or comments made by earlier participants and no new themes emerged in the analysis.[10] All participants were staff or students at the University of York.

Each session lasted for approximately 1 hr. At the start of the session, participants were screened for colour blindness using Ishihara plates. The 16 male participants all displayed some form of red/green CVD; the female participant was a near achromat (she is referred to as #13*, the asterisk marks the difference). The Ishihara test was used because it is an effective screening test that is quick and easy to administer. It does not provide a reliable diagnosis of the precise form and extent of an individual's colour blindness, which would require longer and more complex tests, including the use of an anomaloscope to distinguish dichromats and anomalous trichromats (National Research Council (US) Committee on Vision, 1981). However, since we were interested in collecting qualitative data about a range of experiences that would allow us to identify general features of CVD experience, we opted for the simpler and quicker test.[11]

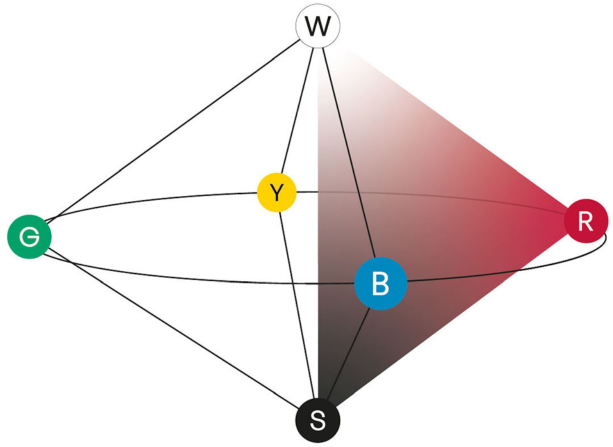
[8]For similar reasons, experimental philosophers have used different methods to investigate other phenomena, such as the semantics of colour adjectives (e.g., Hansen & Chemla, 2017) and non-linguistic inferences (e.g., Tieu, Schlenker, & Chemla, 2019).

[9]For a pioneering example of the use of qualitative methods in philosophy, see Naess's (1938) work on truth. More recent examples include Womack and Mulvaney-Day (2015), and Pohlhaus Jr (2015); and in the phenomenological tradition, see for example, Ratcliffe (2014). The title of Pohlhaus's paper refers to encounter at an x-phi conference in which she enquired about the use of qualitative methods and received the reply: "Are you serious? Do you *really* want to ask Grandma what she thinks." For an overview and defence of qualitative methods in x-phi, see Andow (2016).

[10]This combines what Saunders et al. (2018) identify as "inductive thematic saturation" and "data saturation." Answers to the question of how many participants are sufficient for a qualitative study vary widely, but the current sample size is consistent with Guest, Bunce, and Johnson's (2006) suggestion that for most projects saturation is achieved within 12 interviews and Francis et al.'s (2010) slightly higher estimate of 17 interviews.

[11]The test provisionally suggested that the sample contained eight protans and three deutans; six participants were unclassified.

FIGURE 2 Natural Colour System (NCS) colour space. The NCS colour space is a three-dimensional space defined by the six elementary colours. Reproduced by permission of NCS Colour AB, Stockholm 2021



Sessions consisted of a semi-structured interview. In the first part, participants were asked about their experience of a variety of coloured stimuli. Participants then put on the EnChroma glasses, and were given 10 min to acclimatise to them. During this period, they were encouraged to look at a variety of different objects, and if they were willing and able, to walk around outside. During the second part of the session, they repeated the tasks from the first part of the interview (with the exception of Elementaries) while wearing the glasses. They also answered more general questions about their prior knowledge and expectations of the glasses, and their experience of wearing them. Finally, participants retook the Ishihara test while wearing the glasses.

The tasks that participants were asked to perform included the following:

Elementaries: Participants were presented with a representation of NCS colour space showing the NCS elementary colours (the elementary hues plus black and white). For each colour, participants were given 30 s to name as many things, either in the room or in the world, that looked to be that colour. Once they had done this for all six colours, they were then asked to name them. Colours were presented in the following order: green, blue, white, black, yellow and red. The representation was printed on B2 paper (50 × 70 cm) and each colour was 6 cm diameter. (The representation was similar to Figure 2, but without the red triangle representing a cross-section through the space or labels on the elementary colours.)

Hue Circle: Participants were asked to describe what they saw as they scanned clockwise around the NCS colour circle with the NCS notation obscured (Figure 1). They were also asked to identify the colours at the cardinal and ordinal compass points in a set order: yellow, blue-green, yellow-green, red, blue, orange, green and purple. The representation was on B2 paper and individual patches were 3.8 × 2 cm.[12]

[12]This task is similar to a self-experiment Pole (1859) reports in which he describes Chevreul's colour circle of 1854. Pole's description is suggestive of the standard view, although as Byrne and Hilbert note there are "only a handful of published cases like Pole's" (Byrne and Hilbert 2010, p. 268). Chevreul's colour circle consists of more coloured patches than the NCS colour circle (72 rather than 40) and is not structured around the four psychologically elementary hues identified by Hering (yellow, red, blue and green). Rather, the three subtractive "primary" colours, red, blue and yellow (pigments of which can be used to mix many other colours) are spaced 120° apart, with the "secondary" colours green, violet and orange intermediate between them. For discussion of different senses of "primary" colour, see, for example, Arnkil (2013, pp. 72–73). See also Broackes (2010, pp. 368–373) for discussion of a series of proposed experiments, some of which are similar to those reported here.

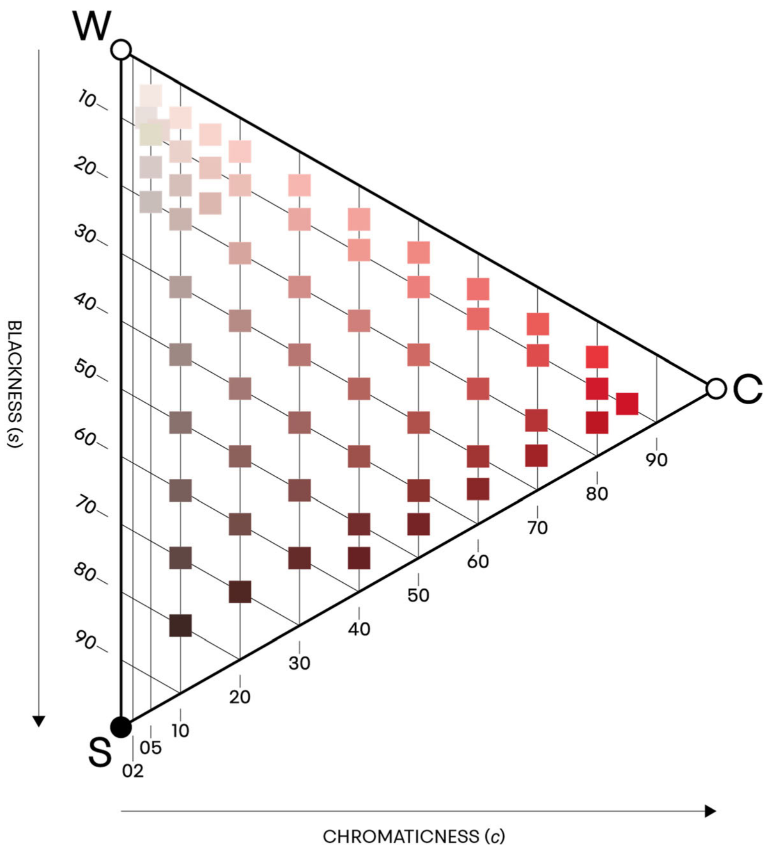


FIGURE 3 Natural Colour System (NCS) colour triangle for the hue Y90R. The colour triangle is a cross-section through NCS colour space. "W" stands for white, "S" stands for black, and "C" stands for chromaticness. Chromaticness decreases from right to left and blackness increases along the lines parallel to WC. Perceived resemblance to whiteness (w) = 100 – (chromaticness (c) + blackness (s)). Reproduced by permission of NCS Colour AB, Stockholm 2021

Red Triangle: Participants were asked to describe their experience of an NCS colour triangle (also on B2 paper), the right-hand apex of which was Y90R, the red sample adjacent to due east on the hue circle (Figure 3). First, they traced a horizontal line from the right-hand apex, across a line where the samples differ in chromaticness. Second, they scanned around the perimeter of the triangle, from the right-hand apex to the top (as chromaticness decreases and visual resemblance to white increases), from the top left-hand corner to the bottom left-hand corner (as chromaticness is constant and the visual resemblance to black increases) and from the bottom left-hand corner back to the apex (as chromaticness increases and the visual resemblance to black decreases).

Sorting: Participants were asked to sort 12 coloured papers into "groups that seem natural" to them; they could sort them into as many piles as they wanted, and take as long as they wanted. Four of the papers were colours adjacent to the cardinal compass points of the NCS colour circle (Y90R, R90B, G10Y Y10R). Four papers were lighter versions of these colours and four papers were darker versions of these colours. The papers were 2.3 × 2.3 cm presented on a white background.

All sessions were conducted in the Department of Philosophy at the University of York. Sessions took place during daylight hours, with overhead office lighting complementing natural light from the windows. The EnChroma glasses were Receptor Fitovers with Cx3 Sun lenses, which EnChroma describe as their most "versatile" lenses, and appropriate for mild, moderate and strong deutans and mild and moderate protans.[13]

[13]https://enchroma.com/pages/lens-guide (accessed February 26, 2020).

Sessions were audio-recorded and transcribed, and transcripts were thematically analysed with NVivo12, a qualitative data analysis software package that can be used to code and analyse text.

One of the participants (referred to as #5 and identified as protan) was an amateur painter, and later reproduced the representations used in ELEMENTARIES and HUE CIRCLE both with and without EnChroma glasses (Figures 4–7).

Ethics approval was granted by the Arts and Humanities Ethics Committee at the University of York.

3 | THEMATIC ANALYSIS

Rather than describe responses to each task separately, the results are presented thematically. Key themes included experiences of red (Section 3.1), green (Section 3.2), binary hues, particularly purple and orange (Section 3.3), pink (Section 3.4), general features of CVD experience (Section 3.5) and experiences with the glasses (Section 3.6). Analysis revealed repeated mention of particular objects in participants' reports. The most interesting of these—skin, leaves, trees and bluebells—are discussed in relation to the central themes that they best illuminate.

3.1 | Red

Without glasses, the NCS elementary red at due east in HUE CIRCLE was variously described as brown (#7), brown or red (#3, #5), "dull, washed out ... maroon" (#12), brown-tinged red (#10), "brown-green" or terracotta (#15) and deep red or crimson, with the immediately following colour in the hue circle looking "very dark grey" (#14). One participant (#6) initially identified it as black, though changed this to red on closer inspection, and the participant who was a near achromat (#13*) described it as looking black, but guessed it might be red.

While the majority of participants described reds as darker without the glasses, one participant described due east as "pinky-red, that's like a faded car colour" (#4). This was consistent with the depiction of the NCS colour circle by the artist (#5), who without the glasses painted the eastern region of the circle lighter in colour than while wearing the glasses (Figures 4 and 5). It is possible that these differences reflect between-participant differences in forms of colour blindness. Viewing context, however, may also be an important factor: Note, for instance, that the artist who depicted the eastern region of the colour circle using lighter reds without glasses described due east (in HUE CIRCLE) as brown or red; he also depicted the red in ELEMENTARIES using a vibrant red, in this case depicting green using a light brown-orange (Figures 6 and 7).

Taking these descriptions at face value, what is common to all these experiences—whether the samples appeared lighter, darker, brownish or washed out—is that reds appeared "less red." In some cases, this appears to be a matter of reds appearing to have a lower degree of chromaticness (c) and a greater resemblance to black (s) or white (w) (Figure 3).[14] The descriptions of reds as looking brownish suggest a further way in which they may sometimes have appeared "less red." Browns are dark yellows and oranges (Quinn, Rosano, & Wooten, 1988). Within the NCS, they are located in the central regions of the colour triangles for the hues that

[14]In the NCS, visual resemblance to white, $w = 100 - (c + s)$. See Sivik (1997).

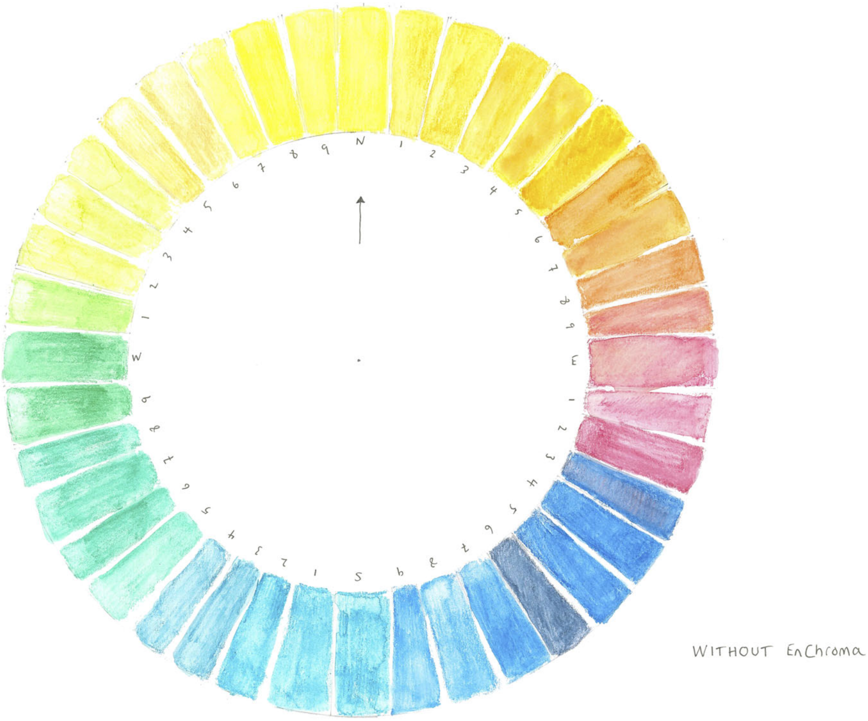


FIGURE 4 Participant #5's representation of the Natural Colour System (NCS) colour circle without EnChroma glasses. "N", "E", "S", "W" designate the cardinal compass points corresponding to the NCS elementary hues

lie in the yellow-orange sector of the hue circle; this is a sector of the hue circle in which colours are defined in terms of their visual resemble to elementary yellow and elementary red. As well as appearing darker, a red that appeared brownish would also appear "less red" in the sense that it would be seen as having a lesser degree of resemblance to elementary red, and so a greater degree of resemblance to elementary yellow.

It is worth emphasising, however, that performance on Hue Circle was by no means uniformly poor. Some participants demonstrated no particular problems with reds, and a number of those mentioned above still identified reds as red—albeit a different shade of red (e.g., brownish-red), with some uncertainty, or on further investigation.

Only one participant identified NCS elementary red as green—specifically, as "brown-green" or "terracotta"—although when prompted he clarified that it was "not at all" like the green that he saw at due west. Rather, he reported that it looked the same colour as the red circle in Elementaries that he (correctly) identified as red, explaining:

> I know it's red because to me it has more brown in it and sort of based upon my understanding and experience I'm like that has to be red then. (#16).

Similarly, in Sorting, only one participant (#11) sorted the mid-red and mid-green samples (the samples located on the colour circle) into a single pile.

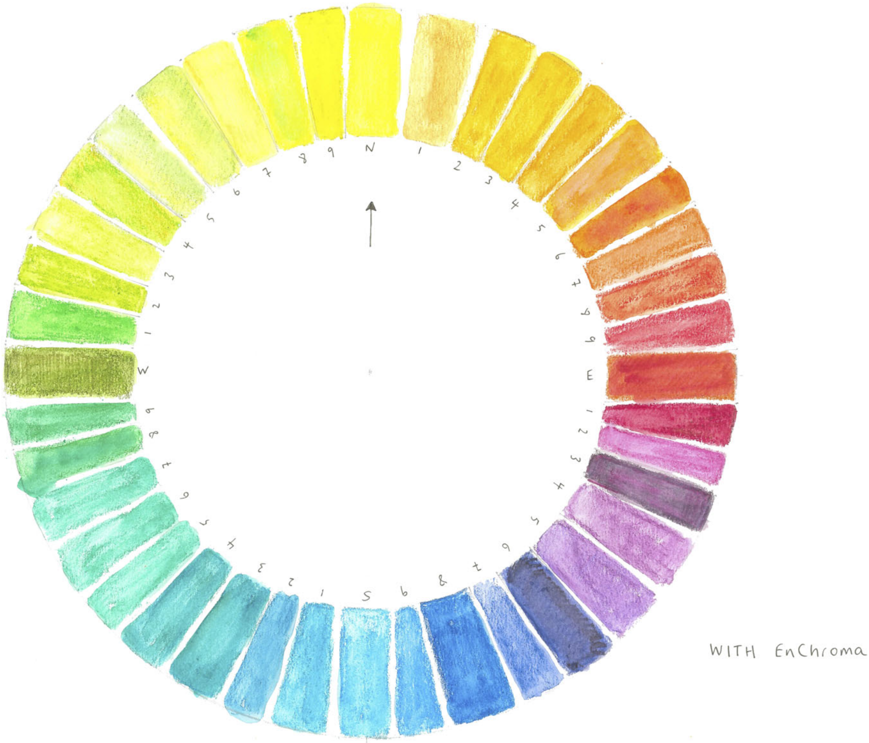


FIGURE 5 #5's representation of the Natural Colour System (NCS) colour circle wearing EnChroma glasses. "N", "E", "S", "W" designate the cardinal compass points corresponding to the NCS elementary hues

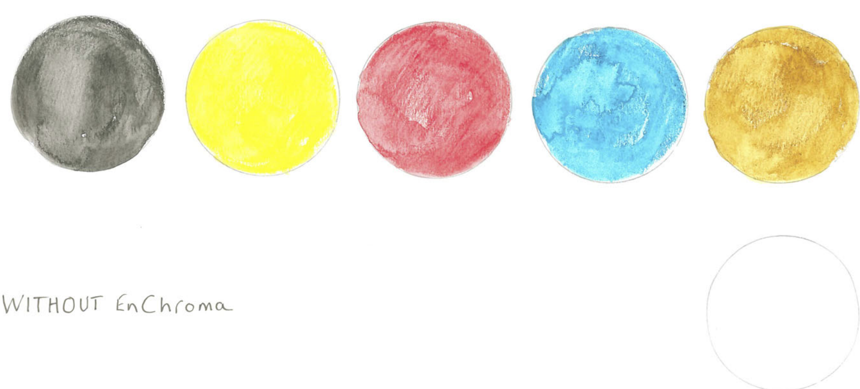


FIGURE 6 #5's representation of the Natural Colour System (NCS) elementary colours without EnChroma glasses

In the ELEMENTARIES task, colour-blind participants could name on average fewer red objects in 30 s ($M = 3.8$, $SD = 2.2$) than participants in a comparison group of 20 normal trichromatic perceivers ($M = 6.6$, $SD = 4.2$, $t(35) = -2.467$, $p < .05$, two-tailed test).[15] However, only two

[15] All the means for the colour-blind group were numerically lower, but the only other significant difference was green (Section 3.2).

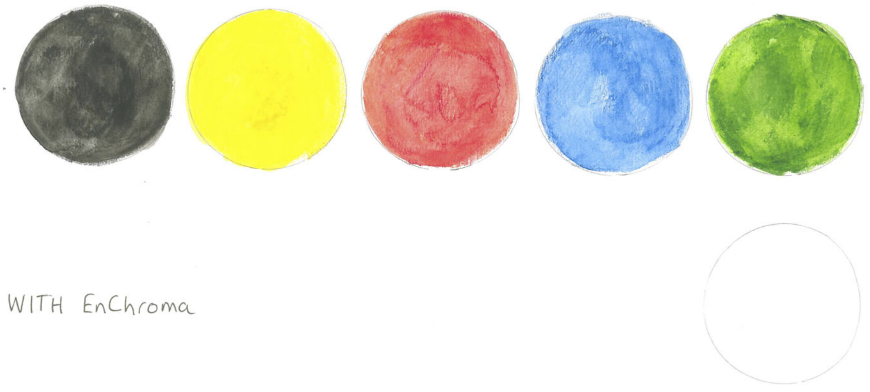


FIGURE 7 #5's representation of the Natural Colour System (NCS) elementary colours wearing EnChroma glasses

were unable to identify *any* objects that looked to be the colour of the red circle, and the error rate was low ($n = 2$, 3.0%). In general, most participants in both groups employed a mixed strategy in this task, naming both objects that they knew to be that colour (e.g., stop signs for red) and also objects that they could currently see (e.g., books, office equipment, and furniture). It was notable, however, that four (24%) colour-blind participants did not identify any red objects by sight, relying instead entirely on prior knowledge.

Performance on Red Triangle was also striking. Without glasses, all participants correctly identified that the samples along the horizontal line from the right-hand apex, which differ in chromaticness, appeared to change in colour. They also all identified that samples changed in colour around the perimeter of the triangle, and all correctly identified the colour at the apex as red. 13* struggled most with this task. However, she was still able to identify the apex as red. She was also able to identify, albeit with some hesitation, that there was a colour change across the horizontal line, and for the most part that the colours changed around the perimeter of the triangle, although she misidentified the colours on the top side of the triangle as transitioning from red, through blue or green, to yellow then white, and could not see the colour change on the bottom side of the triangle, from black to red.

Four participants struggled with samples with low chromaticness at the left-hand side of the triangle. Three (#3, #10 and #16) were unsure whether the sample at the far left was grey or green, and one described the vertical left-hand side of triangle as moving (top to bottom) from "a pinky green, down to a very, very dark green, dark red ... it's a confused kind of red kind of green, if that makes any sense?" (#9) Similarly, in Sorting four participants (#6, #10, #14 and #15) placed the light-green and light-red samples into a single pile.

So, although many CVD perceivers exhibited difficulties with reds, particularly samples with low chromaticness, the ability of participants to identify and describe reds was not altogether absent.

3.2 | Green

Difficulties with green were generally less pronounced than for red. All participants correctly identified due west in the NCS hue circle as green. Sometimes there was evidence that due west appeared a different shade of green than it would to a normal trichromatic perceiver:

> How would I describe it? A lime-green, yes I think I'd describe that as a lime-green. (#6).

Sometimes the identification of west as green was with a greater or lesser degree of uncertainty, for instance:

> Green. Yellow. Green. Green. (#13*).

One participant reported making an informed guess based on the structure of the hue circle:

> I would not want to say that I see the green, it's just that I know those kind of colour circles. And so, I know the green is going to be on there somewhere, and my guess is it's there. (#14).

This participant was still able to correctly identify the green circle in ELEMENTARIES, despite the lack of comparable contextual information on this task. However, as well as describing the green circle as looking the same colour as army clothing, he also described it as looking the same colour as the paperback Clarendon edition of Locke's *Essay concerning human understanding* (which was visible on a bookshelf and has a distinctive brown/terracotta cover) and a brown part of a filing cabinet.

As for red, colour-blind participants named on average fewer green objects ($M = 4.1$, $SD = 2$) than the comparison group ($M = 7.7$, $SD = 3.1$, $t(35) = -4.121$, $p < .01$, two-tailed test), and the error rate for green was the highest ($n = 9$, 11.5%). Every colour-blind participant was able to correctly identify at least one object that looked the same colour as the green circle; however, there was also the greatest reliance on prior knowledge, with 11 (65%) participants identifying no green objects by sight.

One of the most commonly remarked upon objects when wearing the glasses were leaves, with seven participants reporting that they appeared differently (although one participant was disappointed to see little difference). One notable difference was the greater differentiation in the shades of green that could be seen:

> I know when I had the glasses off it sort of looks green, the tree is just a green, whereas I can pick out more dark greens and lighter greens and different shades in the tree itself rather than it just being a one colour almost. (#8).

So again, although CVD perceivers exhibited difficulties with greens, they were nonetheless often able to identify and describe green.

3.3 | Binary hues, including purple and orange

Samples that are intermediate between the cardinal compass points in the NCS colour circle are "binary hues." These hues are "psychologically composed" of the colours at the two adjacent cardinal compass points.

Many participants exhibited no particular problems with many of the binary hues. In HUE CIRCLE, many were able to identify and describe colour transitions around the hue circle, for instance:

> N[orth] is yellow, and as we move around them they become more orange so that by four [Y40R] it's definitely an orange colour to me and then it's getting darker, the orange is becoming red so that by the time it's the east, it's red (#10).

Similarly, most participants were able to correctly identify most of the ordinal compass points.

A few participants described some of the binary hues as looking grey. The participant who best exemplified this described the sample immediately following due east (red) as looking "very dark grey." He also described large sections of the southern hemisphere of the circle, including the quadrant from due south (blue) to due west (green) as looking either green, grey or brown:

> At number seven [B70G] it's like sea green, I believe, and number eight [B80G], again it's a green. However, if I was told that they were grey, I would not be able to argue with someone. Or even if someone told me they were brown. (#14).

Similarly, #5 struggled to identify south-west (turquoise): "Grey, blue, grey. I'm not sure." He also described the next three samples (B60G–B80G) as looking grey—although on a different occasion he was nevertheless able to fairly faithfully reproduce the left-hand side of the NCS colour circle (Figure 4).

However, while a few participants described some binary hues as looking grey, where participants had difficulties with binary hues they were more commonly either uncertain about the colour of a sample, or else described samples as looking to be some other hue. The most striking example of this was purple. Thirteen participants either reported difficulties with, or made mistakes involving, purple. #5's depiction of the hue circle without glasses (Figure 4) is representative of the kinds of mistakes participants tended to make, with southeast and adjacent samples often being described as blue, or else with participants identifying these as purple but with some uncertainty.

These difficulties were reflected in the strong reactions of three participants while wearing the glasses to bluebells outside the Department that were flowering during the early stages of testing. Two of these reported that the bluebells looked a kind of light or pale blue without the glasses, but appeared strikingly different with them, for instance:

> Bluebells looked almost purple but they just stood out massively compared to the ground around them … the colour was so much brighter, almost blinding nearly like, incredible … It was like a violet, when you get a UV light, it was that kind of … like a neon purply-blue. (#4).

While purple was the most common locus of difficulties amongst the binary hues, a few participants found it difficult to distinguish orange and green. For example:

> So north is yellow and, it turns into … The colour is different now, but I still would not know what it was. Maybe it is brown. Yellow, becoming, yellow turning into brown, through shades of … green or orange. I think, those two and three [Y20R, Y30R] might be green actually rather than orange. (#3).

Another described the north-west point of the compass as "orange, I don't know why, but orangey, possibly green" (#14).

These difficulties with binary hues like purple (red-blue) and orange (yellow-red) are plausibly related to difficulties with the elementary hues from which they are psychologically composed. However, as in the case of the elementary hues, many participants nevertheless exhibited an ability to identify and describe many of the binary hues.

3.4 | Pink

The colour category "pink" encompasses binary hues between red and purple in the NCS colour circle (with up to around 30% visual resemblance to blue), as well as compound colours that have a visual resemblance to red and white.

Like the adjacent purples, the binary pinks in the hue circle caused some participants some difficulties, although for the most part it was lighter pinks that were the most interesting. When wearing the glasses, skin conventionally labelled "white" was mentioned by eight participants; five were particularly struck by the way that skin appeared.

Some participants described skin as looking "more colourful" (#12) or redder, almost as if people have eczema (#2). Others reported that skin (possibly) appeared a different colour while wearing the glasses:

> The first thing I noticed was my skin colour … I always used to paint people green actually, but just a very pale indescribable colour. (#5).

This is consistent with some of the difficulties described above in the RED TRIANGLE and SORTING tasks, where some participants had difficulties distinguishing light reds from light greens.

Another participant described skin as normally looking beige. He also noted that the glasses enhanced his awareness of chromatic detail in skin:

> I could never really understand why people said skin is pink because it wasn't pink to me, it was if anything like a very light beige, and I now look at my hands, in particular, my palms, and I can see that there's a lot more pinkness to them. It's a mottling to it. (#10).

As with purple and orange, where participants exhibited problems with pink these are plausibly related to difficulties with the elementary hue (red) from which it is psychologically composed.

3.5 | General features

Abstracting from experiences of particular colours, a number of common themes about CVD experience in general emerged.

There is some evidence that some perceivers were using strategies to categorise their experiences: For instance, when #16 reports recognising reds on the basis of how brown they are (Section 3.1), or #14 guesses that due west is green based on the structure of the hue circle (Section 3.2). It is striking that in ELEMENTARIES participants tended to name objects on the basis of prior knowledge, not sight. #14 explained:

> [B]ecause I know that I'm colour-blind, that I'm naming things which other people have told me are that particular colour, and then I just repeat back what I'm told.

However, some participants reported that under certain circumstances, even without EnChroma Glasses, their *experiences* change, and they became able to perceive colours that they were previously unable to. For instance:

> PARTICIPANT: throughout my life from being young, I've been told something is a certain colour and I can't unlearn that, almost, whereas I think naturally I might have seen it as another colour altogether.
>
> INTERVIEWER: But does it genuinely look that way, once you've learned it ...?
>
> PARTICIPANT: Yes, once I've learned it, it genuinely does look that colour, yes ... when you told me that this is actually yellow, brown yellow, yeah but okay, I can see that, and when you told me this is greenish, I think this is a green one, it's a lot easier to see. (#10).

Similarly, #6 reports a change in his experience when looking at due east (red) from different distances: Having initially thought it might be black, it looks “claret,” and he “can only see it as red now.” As the board is then moved further away again, he then says it is “probably ... very dark brown,” although he expresses some uncertainty when asked whether it looks to be the same colour as the red office door:

> The sample is too small to tell ... The thing about the door is that I've got a very large panel of red to observe there, a small chip like that is hard to make a judgement about ... I would say it looks darker actually but I don't know that it looks, does it look browner? I don't know. Sorry there's an ambiguity in this. (#6).

In general, there was evidence from a number of participants that context makes an important difference to how well colours can be perceived: Participants who expressed difficulties, or made mistakes, in one context, were often able to easily and correctly identify the very same colour in a different context. As in #6's report above, the viewing distance and size of the sample were often key determinants of how easy it is to perceive the colour of the object. Other responses indicate that illumination is an important factor. #12, for instance, used the flashlight on his phone to look at the samples in the quadrant of the hue circle from east to south (pink, purple, blue).

Another general feature of CVD experience that emerged, and which is reflected in many of the reports above, was that participants often expressed uncertainty about particular colour judgments. In some cases, as in #6's uncertainty about whether the sample at a distance is the same colour as the door, there is some suggestion that this uncertainty reflects an indeterminacy in the experience itself.

3.6 | EnChroma glasses

Unsurprisingly, the glasses, and their effects on experience, emerged as a key theme in the analysis.

All but one participant (#13*) made a comment to the effect that at least some colours seemed “more colourful” while wearing the glasses: For instance, that certain colours seemed brighter or less washed out. When asked whether the experiences they had while wearing the glasses were similar to any other experiences, comparisons included films in HD or Technicolor, neon colours, colours seen under UV lighting, and photos that had been manipulated by turning up the contrast.

A number of participants reported that certain colours and certain objects were easier to discriminate while wearing the glasses. For instance:

> [S]tuff pops more. Like the red car outside, the reds seem to be the big one, like there was a fire escape or emergency instruction sign in the stairwell and it had a couple of red boxes on it and they just like blew up in my face really. (#4).

As in the case of leaves (Section 3.2) and the mottling of skin (Section 3.4), some participants found that the glasses enhanced their ability to perceive local colour differences in what had previously been seen as an homogeneously coloured object. This was also something that two participants reported when looking at tree trunks. For example:

> [W]hen I got closer to it [the tree trunk], across the road, I saw little bits of colours in there. It looked like, I don't know, red or brown, maybe it was brown. Just in there with the trunk where previously it just all looked pretty much one colour, so fairly pale. (#5).

This participant goes on to suggest that the increased detail may be contributing towards a better sense of overall depth perception (something also suggested by #12):

> I think that's maybe what's giving it more depth, there's lots of little bits now, components and things that are contributing to the overall effect, picture. (#5).

Few participants (at most four) were inclined to agree that the glasses completely corrected their colour vision—although many were sensitive to the difficulties in making this kind of inter-personal comparison. Nevertheless, a majority (10, 59%) felt that the changes to their colour experience were sufficiently significant that they would at least consider buying a pair of the glasses. Among the positive responses, five said straightforwardly that they would. One participant said that he would buy a pair, but not for normal use, explaining:

> I wouldn't want my world to be like this, but I would buy it out of curiosity just to see what more I'm missing out on if that makes sense. (#2).

The remaining four participants who gave a positive response said that the price of the glasses would need to be reduced dramatically before they considered purchasing a pair.

One of the most interesting questions is whether the glasses enabled participants to see new colours; this was also a difficult question to answer for some. The majority of participants (12, 71%) did not report seeing any colours that they had not seen before. Some of those who fall into this group expressed surprise that the differences were not more pronounced:

> I suppose I thought my vision was like extremely different from what other people see, whereas if this is what other people see, I suppose it's not that different, it's just a few subtle changes. (#3).

The responses of the remaining five participants are more difficult to interpret, but can either be understood as reporting seeing a new shade (or determinate) of a (determinable) colour that they have previously seen other instances of, or else as seeing a new (determinable) colour entirely.[16] The following were tentatively coded as expressing the first of these options:

> [T]he skin thing was the biggest thing I've spotted ... I've seen pink before but I'm not sure I've seen this colour before ... It's a sort of orangey-pink. (#10).

> Participant: the pinkie colour [in my skin] has really jumped out. ... I don't remember seeing that colour before, no.
>
> Interviewer: ... Does it look like it might be a mixture of any other colours?
>
> Participant: Well, reddish ... it's hard to say. Not orangey, but almost yeah like, like a tanned kind of, yeah pink. (#5).

> The bluebells might be a bit of a new colour to me. I can't remember seeing that, no ... It looks like a type of purple that you just smacked the contrast up on like an image editing programme ... It looks like purple but with a bit of red to it almost. (#2).

> Participant: suddenly with the glasses ... the colour [of the bluebells] was so much brighter, almost blinding nearly like, incredible ... It was like a violet, when you get a UV light, it was that kind of ... like a neon purply-blue.
>
> Interviewer: So, before you put the glasses on did you know what the colour of the bluebells looked like?
>
> Participant: Yes, I could picture it in my mind. (#4).

In these cases, the newly perceived colour is described as being a version of, or like, another colour that the participant had previously perceived—or interestingly in the final case, imagined. One response, however, more clearly seemed to suggest the view that the newly perceived colour was a completely new kind of colour:

> I don't think I've ever seen that colour, I don't think I've ever seen purple like that ... I will know now that the purple I see is not what it is. (#16).

Although a number of participants noticed differences in the way that reds and green appeared, it is notable that when asked whether they had seen any new colours, no one claimed

[16]These responses include participants provisionally identified as both protan and deutan.

to have seen reds or greens for the first time; all the examples of possible new colours were pinks and purples.

4 | DISCUSSION

We have reported the results of a series of semi-structured interviews with colour-blind participants in order to understand more fully the phenomenological character of their experiences. We found that although participants with forms of red/green colour blindness often struggled to make the colour discriminations and identifications that "normal" trichromatic perceivers make, their ability to discriminate and identify colours as red and green was not entirely lacking, and often varies depending on the context of viewing. We also found that it is not just reds and greens that are affected, but binary and compound colours, in particular purple, orange and pink.

While the vast majority of participants found that EnChroma glasses made at least some difference to their experience, only a few reported seeing new colours, and the most striking differences were with experiences of purples and pinks. This study provides some evidence that the ability of colour-blind perceivers to discriminate and identify reds and greens depends on perceptual *experiences* of these colours, while at the same time suggesting that these experiences also often exhibit a certain degree of indeterminacy.

4.1 | What is it like to be colour-blind?

The results of this study militate against the standard view of colour blindness, according to which someone who is red/green colour-blind is completely unable to see reds and greens, but sees only yellows, blues, blacks, whites, and shades of grey (Section 1.1).

One response on behalf of the standard view is that none of the participants were "truly" colour-blind, and that the standard view would at least adequately describe the experience of a someone whose colour blindness was "complete." The Ishihara test did not allow us to distinguish between dichromats and anomalous trichromats, and based on the relative prevalence of these conditions we would expect a substantial proportion of the participants to be anomalous trichromats. Even so, the sample clearly contained participants with relatively severe forms of CVD, and the standard view does not fit easily with their experience. Besides, even if the standard view does correctly describe the experience of an "ideal" dichromat, this does not give us any useful insights into the lived experience of the majority of CVD perceivers who do not fit such a template.

A different response on the behalf of the standard view is that we cannot take at face value the descriptions of their experiences that CVD perceivers give using ordinary colour terms. The current study relies in part on descriptions of the experiences of CVD perceivers that employ ordinary colour vocabulary, from general terms such as "red" or "green" to more specific terms such as "lime green" or "maroon." However, why should we suppose that CVD perceivers' use of ordinary colours terms reflects experiences that are phenomenologically similar to those of normal trichromatic perceivers? Perhaps, instead, colour-blind perceivers engage in some form of inference from a limited palette of experiences, correlating the limited set of colours that they see with the colour categories of normal trichromatic perceivers. This, for instance, is how Jameson and Hurvich (1978) explain how a majority of perceivers who made characteristic confusions in a diagnostic Farnsworth D-15 sorting task could nevertheless still correctly name the red and green caps. Assuming that their experience is limited to yellows, blues and achromatic colours, they suggested that colour-blind perceivers can use a rule to correlate samples of different lightness with "normal" colour terms.

The current study suggests that this response on behalf of the standard view is not convincing. First, in Red Triangle all participants perceived the samples along the horizontal and around the perimeter as differing in colour. Second, while there is evidence that some perceivers seemed to be using strategies to categorise colours in something like the way Jameson and Hurvich suggest, the type of experience from which the participant is inferring does not appear to be achromatic, as on the standard view. For example, #16 describes reds and greens as differing in their *chromatic* properties, namely reds look *browner* than greens, and it is this to which his judgment using ordinary colour terms appears to be sensitive (Section 3.1). Third, other participants report that under certain circumstances, even without EnChroma glasses, their *experiences* themselves change, and they become able to perceive colours that they were previously unable to (Section 3.5).

Indeed, it is striking that the best candidates for newly perceived colours while wearing the glasses were not reds and greens, but pinks and purples. Why might this be? One plausible explanation in light of the performance of CVD perceivers across the range of different tasks reported here is that "red/green colour-blind" perceivers are actually already able to perceive reds and greens, at least to some degree and in certain circumstances. However, the difficulties they have with these colours are exacerbated where either the chromaticness of these colours is reduced or where the colours are phenomenally mixed with other elementary hues (e.g., purples). By enhancing the way that reds and greens appear in general, the glasses may enable some CVD perceivers to perceive, or at least better perceive, colours that are phenomenally related to red and green.

On the more general question of the relationship between the phenomenology of the experiences of CVD perceivers and their use of colour vocabulary, the results of the current study may not enable us to rule out decisively the theoretical possibility that CVD perceivers use colour terms in a similar way to normal trichromatic perceivers despite having experiences that differ radically in their phenomenology—just as it may not be possible to rule out decisively the theoretical possibility that otherwise normal trichromatic perceivers differ radically in the phenomenological character of their experiences (e.g., through inversions in colour space). Nevertheless, the hypothesis that the experiences of CVD perceivers do not differ substantially, at least in favourable circumstances, provides a straightforward explanation of the fact that across a range of tasks, and across many areas of colour space, many CVD perceivers are able to use colour vocabulary in a way that is consistent with normal perceivers. It also provides a straightforward explanation of the effects of wearing the glasses, namely that they enhance existing abilities to perceive reds and green.

The current results also militate against both the alien colour and revised reduction/revised alien views. According to the alien colour view, the colours that colour-blind perceivers see have no location in trichromatic humans colour space at all. However, when wearing the glasses, none of the participants reported any differences in the way that blues or yellows appeared. Moreover, when they reported new experiences of (shades of) pink and purple, they seemed to suggest that these new colours were related to colours that they had previously experienced, as if these new colours could be located within an enlarged colour space that contained the colours they had previously seen as a proper part.

According to the revised reduction/revised alien view, colour-blind perceivers see achromatic colours, unique blue, and unique yellow in the same way as normal trichromatic perceivers; unlike normal trichromatic perceivers, binary hues appear simply yellowish or bluish (to different degrees). However, although there was some evidence that participants' experiences were indeterminate, there was no evidence that they were indeterminate in the way that this account predicts. For instance, when describing the hue circle, participants would often talk about colours transitioning, for example, from yellow, through orange, to red, and binary hues would be described as becoming more or less similar to the elementary hues they were between (e.g., oranges becoming redder as they get closer to east). Moreover, in describing before-after changes brought about by the glasses, participants would often characterise the change as a change from seeing one determinate colour to another, rather than from seeing an indeterminate colour to seeing a determinate colour: For instance, bluebells changed from light blue to purple.

The current results instead support the common colour view, complementing existing evidence that colour-blind perceivers are able to perceive reds and green, at least when the conditions are favourable. The current results also provide qualified support for Broackes's more specific claim, made in part on the basis of careful first-person phenomenological observation, that experiences of CVD perceivers sometimes exhibit a certain kind of indeterminacy, or imprecision, that can resolve after further exploration or exposure to the stimulus. On this view, experiences do not necessarily present objects as having maximally determinate colours that correspond to precise points in colour space (e.g., unique blue, perfectly balanced orange), but rather sometimes present colours indeterminately or imprecisely, in such a way that they correspond to more or less extensive regions of colour space (e.g., bluish, reddish-orangish, greenish-brownish-greyish). The support for this claim is qualified as it is difficult to determine categorically whether the uncertainty that participants expressed reflected the indeterminacy of their perceptual experiences, or was just a feature of a post-perceptual judgment in which they attempted to assign a perfectly determinate, precise experience to a category. This is an instance of a more general difficulty in attempting to distinguish perception from post-perceptual judgment.[17] Nevertheless, the findings of this study are consistent with Broackes's claim.

Understanding what it is like to be colour-blind is philosophically interesting and important in and of itself. However, non-standard forms of experience, like the experiences of CVD perceivers, are also theoretically interesting because of their implications for wider questions about perception and consciousness. The possibility that the experiences of CVD perceivers sometimes present colours indeterminately or imprecisely is a case in point. This claim is contrary to a long-standing, and intuitively tempting, view that we only perceive maximally determinate properties; in the case of colour, properties that correspond to precise locations in colour space. It also presents problems for traditional explanations of this putative phenomenological fact: For instance, explanations that appeal to "sensations" or "qualia," or else sense-data with only fully determinate properties (see also Chisholm, 1942). If the colour experiences of CVD perceivers present colours indeterminately, then this presents a direct challenge to the generality of these views: It provides a case in which conscious visual experience is not of determinate colour properties, and so does not plausibly involve qualia or sense-data so understood.

[17]Compare discussions of whether we can perceive "high-level" properties such as *being a pine tree* (Siegel, 2010).

More positively, non-standard forms of experience can also help to illuminate the experiences that they are non-standard forms *of*, by prompting us to consider "normal" experiences anew. It is, for instance, tempting to assume that the colour experiences of normal trichromatic perceivers are themselves fully determinate: that at each point in the visual field, colours are presented with maximum determinacy, such that they correspond to precise points in colour space. However, reflecting on the experiences of CVD perceivers can help normal perceivers to "bracket" habitual assumptions and reconsider their own experiences.[18]

One way of illustrating this is by considering in more detail what would it be for colour perception to be indeterminate. Rather than focusing on stereotypical cases of colour perception in which we are looking directly at a well-illuminated object, considering other types of experience can help to loosen the grip of the assumption that our own colour experiences are always fully determinate. How colours appear in peripheral vision provides one potential example (e.g., Dennett, 1991; Hardin, 1988, p. 101). In normal trichromatic perceivers, colour vision is not entirely absent in peripheral vision. However, red/green discrimination in particular declines as eccentricity increases—although as in the case of colour-blind perceivers, increasing the size of the stimulus improves our ability to perceive colours in peripheral vision (e.g., Hansen, Pracejus, & Gegenfurtner, 2009).

4.2 | Are EnChroma glasses effective?

One of the subsidiary aims of the study was to assess the efficacy of EnChroma glasses. Emotional online videos of people trying on EnChroma glasses for the first time stand in contrast to the negative assessments of some previous psychophysical studies (e.g., Gómez-Robledo et al., 2018; Mastey et al., 2016). This is the first study to use primarily qualitative methods to assess whether the glasses are effective. While qualitative methods cannot allow us to quantify the statistical effect size of wearing the glasses, they do provide a richer, person-centred, understanding of the experience of colour blindness and the changes that the glasses bring about. This study suggests a view that is intermediate between that presented by online videos and previous psychophysical studies, highlighting in particular the selective nature of the effects of the glasses.[19]

The effects of the glasses are selective in a number of ways. First, the glasses are more effective at bringing about an experiential change for some perceivers than for others. This is consistent with Gómez-Robledo et al.'s (2018) assessment that there will be no optimal filter for different types of CVD perceiver, given the underlying differences in their retinal receptors. None of the participants reacted in the emotional way that participants in online videos sometimes do; indeed, for some, it took a while for the glasses to have a discernible effect. However,

[18]Compare Merleau-Ponty's (1945) use of pathological and non-standard cases to illuminate the structure of ordinary conscious experience. Considering colour vision in infants, for instance, Merleau-Ponty argues that "psychologists themselves were simply not yet able to imagine a world in which colors are indeterminate, or a color that is not a precise property" (1945, p. 32).

[19]The results of this study are consistent with a more positive recent appraisal of EnChroma glasses that found changes in the colour vision of anomalous trichromats after sustained use over a 2-week period (Werner, Marsh-Armstrong, & Knoblauch, 2020). This study was based primarily on quantitative analysis, although contained some limited qualitative data. These reports are consistent with our findings: For instance, one participant reported chromatic nuances in objects that had previously seemed homogenous, saying "I now see that my girlfriend's brown hair has hints of red" (Werner et al., 2020, p. 3014).

whereas only one of Gómez-Robledo et al.'s participants reported *any* subjective improvement to the colours of their surroundings when looking through the glasses, almost all of our participants reported some experiential change, ranging from the subtle to the more substantial.

Second, the glasses are more effective at bringing about experiential changes in some contexts than others. As in previous studies (e.g., Gómez-Robledo et al., 2018), no one who failed the Ishihara test without the glasses passed the test while wearing them. In this sense, the glasses do not "correct for" colour blindness. However, this does not show that the glasses are entirely ineffective. Previous studies have often focused on assessing the performance of CVD perceivers on standard colour blindness tests, which involve stimuli that are designed to be difficult for CVD perceivers to see. By contrast, the current study used a broader range of stimuli, including ordinary objects in a real-world setting, that existing research suggests are easier for colour-blind perceivers to perceive. If, in general, the ability of CVD perceivers to see colours is context dependent, then poor performance in unfavourable conditions is consistent with the glasses enhancing performance in more favourable conditions: For instance, when stimuli are three-dimensional physical objects rather than spectral lights, when they occupy a larger region of the visual field, and when they can be seen against differing backgrounds and under varying illumination.

Third, the glasses are selective in the types of colour experience that they bring about the most noticeable changes in. Although the appearance of reds and greens were affected to some degree for some perceivers and in some contexts, it was differences in some participants' experiences of pinks and purples that were the most striking.

Where the glasses brought about an experiential change, it is a further question whether the glasses enabled CVD perceivers to see the world as normal trichromatic perceivers do. Gomez-Rabelo et al. argue that notch filters like those used in EnChroma glasses can only bring about a change in how colours appear, they cannot enable perceivers to see new colours. The current results do not provide clear evidence that any participants perceived entirely new colours, as opposed to new shades of previous seen colours; and few participants felt that the glasses entirely corrected their vision.

However, even if the glasses do not enable CVD perceivers to see new colours, the difference they make may nevertheless be personally significant to CVD perceivers, and it is this kind of personal significance that qualitative methods are particularly well-suited to identify. First, if the common colour view is correct, then CVD perceivers are not necessarily entirely unable to perceive the colours that normal trichromatic perceivers can; enhancing how these colours appear may itself be sufficiently valuable. Second, even if the glasses only selectively change how some colours appear, these changes may nevertheless have important personal significance. Given the interest we have in seeing ourselves and others, for instance, changes to the way that skin appears are likely to be particularly affecting. Third, some perceivers reported that the glasses enhanced their ability to see local differences in colour, and this in turn is important for visual perception more generally, for instance, the perception of texture and depth (e.g., Chirimuuta, 2015).

4.3 | Experimental philosophy of experience

Finally, what does the current study tell us about the potential of qualitative research methods to enable us to better understand the phenomenological character of experience? Taken as a whole, the results of the study help to establish a coherent picture of the lived experience of colour blindness, that allow us to adjudicate between competing accounts of what it is like by complementing existing evidence in favour of the common colour view. Since one of the aims of the study is to investigate the scope for extending the methods of x-phi, the fact that the results of the study are consistent with existing evidence for the common colour view helps to provide independent "calibration" for the methods used here. To this extent, the current study provides evidence of the value of using qualitative research methods in experimental philosophy in general, and experimental philosophy of experience in particular.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Akins, K. (2014). Black, white and colour. In R. Brown (Ed.), *Consciousness inside and out*. Dordrecht: Springer.

Allen, K. (2016). *A naive realist theory of colour*. Oxford: Oxford University Press.

Andow, J. (2016). Qualitative tools and experimental philosophy. *Philosophical Psychology*, *29*, 1128–1141.

Arnkil, H. (2013). *Colours in the visual world*. Helsinki: Aalto University Press.

Bosten, J. (2019). The known unknowns of anomalous trichromacy. *Current Opinion in Behavioural Sciences*, *30*, 228–237.

Broackes, J. (2010). What do the colour-blind see? In J. Cohen & M. Matthen (Eds.), *Color ontology and color science*. Cambridge, MA: MIT Press.

Byrne, A. & Hilbert, D. (2010). How do things look to the color blind? In J. Cohen & M. Matthen (Eds.), *Color ontology and color science*. Cambridge, MA: MIT Press.

Chirimuuta, M. (2015). *Outside color*. Cambridge, MA: MIT Press.

Chisholm, R. (1942). The problem of the speckled hen. *Mind*, *51*, 368–373.

Cole, B., Lian, K.-Y., Sharpe, K. & Lakkis, C. (2006). Categorical color naming of surface color codes by people with abnormal color vision. *Optometry and Vision Science*, *83*, 879–886.

Dennett, D. (1991). *Consciousness explained*. Boston, MA: Little Brown.

Fischer, E., Engelhardt, P. & Sytsma, J. (2020). Inappropriate stereotypical inferences? An adversarial collaboration in experimental ordinary language philosophy. *Synthese*, https://doi.org/10.1007/s11229-020-02708-x.

Francis, J. J., Johnston, M., Robertson, C., Glidewell, L., Entwhistle, V., Eccles, M. P. & Grimshaw, J. M. (2010). What is an adequate sample size? Operationalising data saturation for theory-driven interview studies. *Psychology & Health*, *25*, 1229–1245.

Francis, K., Terbeck, S., Briazu, R., Haines, A., Gummerum, M., Ganis, G. & Howard, I. (2017). Simulating moral actions: An investigation of personal force in virtual moral dilemmas. *Scientific Reports*, *7*, 13954.

Gómez-Robledo, L., Valero, E. M., Huertas, R. M., Domingo, M. A. & Hernández-Andrés, J. (2018). Do EnChroma glasses improve color vision for colorblind subjects? *Optics Express*, *26*, 28693–28703. https://doi.org/10.1364/OE.26.028693

Guest, G., Bunce, A. & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods*, *18*, 59–82.

Hacker, P. (1987). *Appearance and reality*. Oxford: Blackwell.

Hansen, N. & Chemla, E. (2017). Color adjectives, standards, and thresholds: An experimental investigation. *Linguistics and Philosophy*, *40*, 239–278.

Hansen, T., Pracejus, L. & Gegenfurtner, K. (2009). Color perception in the intermediate periphery of the visual field. *Journal of Vision*, *9*, 1–12.

Hardin, C. (1988). *Color for philosophers*. Indianapolis, IN: Hackett.

Hering, E. (1920/1964). *Outlines of a theory of a light sense*. Hurvich, L., & Jameson, D. (Trans.). Cambridge, MA: Harvard University Press.

Jackson, M. (2015). Resistance to qual/quant parity: Why the paradigm discussion can't be avoided. *Qualitative Psychology*, *2*, 181–198.

Jameson, D. & Hurvich, L. (1978). Dichromatic color language: "Reds" and "greens" don't look alike but their colors do. *Sensory Processes*, *2*, 146–155.

Mastey, R., Patterson, E. J., Summerfelt, P., Luther, J., Neitz, J., Neitz, M. & Carroll, J. (2016). Effect of "color-correcting glasses" on chromatic discrimination in subjects with congenital color vision deficiency. *Investigative Ophthalmology & Vision Science*, *57*, 192.

Merleau-Ponty, M. (1945/2012). In D. Landes (Ed.), *Phenomenology of perception*. London: Routledge.

Montag, E. (1994). Surface color naming in dichromats. *Vision Research*, *34*, 2137–2151.

Naess, A. (1938). *"Truth" as conceived by those who are not professional philosophers*. Oslo: I Komisjon Hos J. Dybwad.

National Research Council (US) Committee on Vision (1981). *Procedures for testing color vision: Report of working group 41*. Washington, DC: National Academies Press.

Palmer, S. (1999). *Vision science*. Cambridge, MA: MIT Press.

Pohlhaus Jr., G. (2015). Different voices, perfect storms, and asking grandma what she thinks: Situating experimental philosophy in relation to feminist philosophy. *Feminist Philosophy Quarterly*, *1*, 3. https://doi.org/10.5206/fpq/2015.1.3

Pole, W. (1859). On colour-blindness. *Philosophical Transactions of the Royal Society of London*, *149*, 323–339.

Quinn, P., Rosano, J. & Wooten, B. (1988). Evidence that brown is not an elemental color. *Perception & Psychophysics*, *43*, 156–164.

Ratcliffe, M. (2014). *Experiences of depression: A study in phenomenology*. Oxford: Oxford University Press.

Reuter, K. & Sytsma, J. (2020). Unfelt pain. *Synthese*, *197*, 1777–1801.

Roberts, P., Allen, K. & Schmidkte, K. (2021). Reflective intuitions about the causal theory of perception across sensory modalities. *Review of Philosophy and Psychology*, *12*, 257–277.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., ... Jinks, C. (2018). Saturation in qualitative research: Exploring its conceptualization and operationalization. *Quality & Quantity*, *52*, 1893–1907.

Scheibner, H. & Boynton, R. (1968). Residual red-green discrimination in dichromats. *Journal of the Optical Society of America*, *58*, 1151–1158.

Siegel, S. (2010). *Contents of visual experience*. New York, NY: Oxford University Press.

Simonuvic, M. P. (2010). Colour vision deficiency. *Eye*, *24*, 747–755.

Sivik, L. (1997). Color systems for cognitive research. In C. Hardin & L. Maffi (Eds.), *Color categories in thought and language*. Cambridge: Cambridge University Press.

Smith, V. & Pokorny, J. (1977). Large-field trichromacy in protanopes and deuteranopes. *Journal of the Optical Society of America*, *67*, 213–220.

Stein, J. (1928). Uber die veranderung der sinnesleistungen und die entsehung von trugwahrnehmungen. In O. Bumke (Ed.), *Pathologie der wahrnehmung: Handbuch der geisteskrankheiten*. Berlin: Springer.

Tieu, L., Schlenker, P. & Chemla, E. (2019). Linguistic inferences without words. *PNAS*, *116*, 9796–9801.

Wachtler, T., Dohrmann, U. & Hertel, R. (2004). Modeling color percepts of dichromats. *Vision Research*, *83*, 33–52.

Werner, J., Marsh-Armstrong, B. & Knoblauch, K. (2020). Adaptive changes in colour vision from long-term filter usage in anomalous but not normal trichromacy. *Current Biology*, *30*, 3011–3015.

Womack, C. & Mulvaney-Day, N. (2015). Feminist bioethics meets experimental philosophy: Embracing the qualitative and experiential. *International Journal of Feminist Approaches to Bioethics*, *5*, 113–132.

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