Comments on How Coloured Maps Might be Seen by Orienteers with Defective Colour Vision

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Designing any colour coding system requires an understanding of how humans see colour. It is well known that some people are 'colour blind', or really, colour vision impaired. Total colour blindness is extremely rare, and the condition is typically only partial. The degree of severity of defective colour vision can vary greatly (by far the majority having only a mild problem).

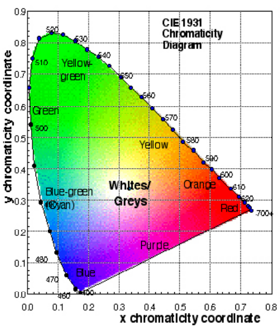
There are 4 different categories of colour vision:

1. **Normal** (all red wave length-receptive, green wave length-receptive and blue wave length-receptive photoreceptors in the eye function normally). Note however, the smaller the patch of colour the harder it becomes to recognise even by a 'colour normal'.
2. **Protan** (uncommon, ~1-2% of men, rare in women) a red/green defect (the red-receptive photoreceptors in the eye are faulty or unreceptive). The defect is typically congenital and without any other associated ocular consequences, but may be acquired from ocular or other nerve diseases.
3. **Deutan** (relatively common, ~6% of men, 0.5% women) a red/green defect (the green-receptive photoreceptors in the eye are faulty or unreceptive). The defect is typically congenital and without any other associated ocular consequences, but may be acquired from ocular or other nerve diseases.
4. **Tritan** (very rare except in some eye diseases) a yellow/blue defect (the blue-receptive photoreceptors in the eye are faulty or inactive). Tritanomaly is more common in ocular disease affecting the elderly, e.g cataract or age-related macular degeneration. However, visual acuity and hence the ability to see fine detail is typically also severely affected, precluding involvement in activities such as reading orienteering maps.

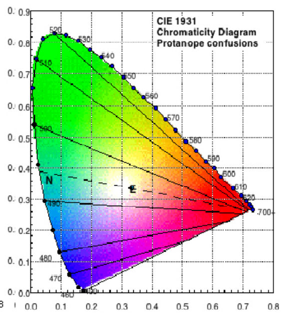
The 3 classes of persons who have abnormal colour vision exhibit a wide range of severity from very mild (referred to as protanomaly, dueteranomaly, tritanomaly) to severe (referred to as having protanopia, deuteranopia, tritanopia or being a protanope, deuteranope or tritanope respectively). Persons with 'anomalous' colour vision only confuse colours in the lighter pastel shades, but are actually able to see the more saturated or intense versions of the same colours sufficiently well to differentiate. Persons with the 'opia' version of a colour vision defect have problems even when colours are relatively saturated. Hence, any two colour-defective persons are unlikely to have identical difficulties interpreting colour coding.

One way of visualising the challenge of colour coding

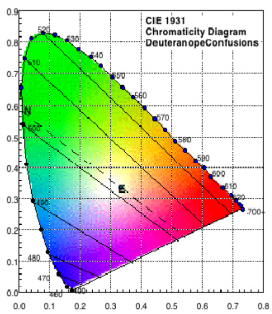
The classes of defects can be represented by looking at the normal colour palette (see Figure 1 from the four diagrams immediately below) and overlaying lines that connect the colours seen by a normal person but which are confused by the person with a particular class of defect. The confusions lines for each class of defect run differently.



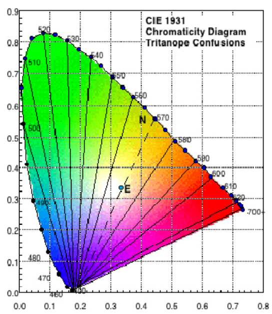
1 Normal colour palette.



2. The Protan confusion lines.



3. The Deutan confusion lines.



4. The Tritan confusion lines.

In Figure 2 the lines emanating from the red corner each portray the main colours that will be confused by the Protan class (e.g. red with yellow with green; red with purple with blue).

On the other hand, Figure 3 shows that the Deutan class is subtly different and though still confusing red with yellow with green, they will only confuse purple with blue.

Notice in Figure 4 that the Tritan class has a totally different orientation of it confusion lines. Blue is confused with green and some yellows, whilst purple is confused with other yellows and reds.

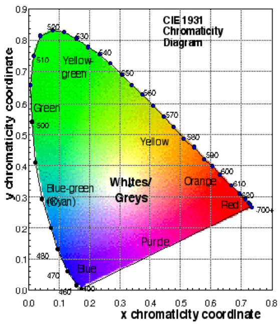
So the challenge is to never use colours lying along any one confusion line for any of the three diagrams! Then one would be sure that the chosen colours are distinguishable by anyone with colour defective vision.

An alternate way of visualising the challenge of colour coding

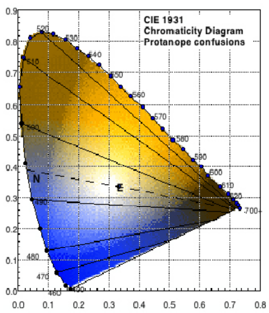
Is there a means to be able to see things represented the way a person with defective colour vision actually sees them?

The web site www.vischeck.com offers such a service in two ways. They will convert any image you upload to their site so you can see how your image is believed to appear to persons with any one of the three classes of colour vision defect. Or, you can download a plug-in 'filter' if you have AdobePhotoshop installed on your computer and then apply this filter yourself to any image you open in Photoshop.

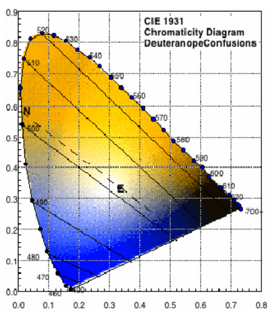
I have converted the figure on the previous page using Vischeck (ignore the confusion lines on Figs 6,7,8). Hence, you can see how the three classes of colour defective persons would be see the original colour palette on the left, were they to have a more severe version of the defect. It can be seen that our orienteering 'yellow – open' and 'green – slow run' are seen as yellow/yellowish-brown or yellow/ochre by the red/green colour defective orienteers. Indeed, the diagram dramatically shows the restrictions on any potential colour code if orienteers with severe colour defects are to be accommodated.



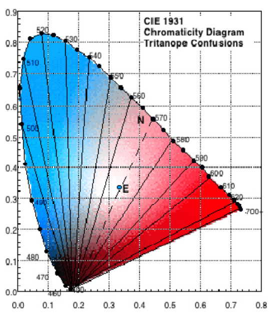
5. Normal colour view.



6. The Protan's view converted through Vischeck.



7. The Deutan's view converted through Vischeck.



8. The Tritan's view converted through Vischeck.

Further considerations

It is not only the eye's functionality that determines the colour of an object. The instrinsic nature of the object and also the light striking it are also factors. The phosphors of your LCD or the pigment used in the ink on the printed page can be defined using red/green/blue specifications. However, even the integrity of the intentions of the creator of a picture may not come to fruition because dyes change with age and will deposit differently on paper, even depending on the type of paper, the type of printer, the speed of the paper feed through the printer (which is affected by the degree of wear and tear it has had), etc. Once the pigment is on the paper, the lighting under which it is viewed is also important because it is this *reflected* light from the pigment on the paper which determines what the eye of the beholder receives. To see an example of what I am describing in this paragraph, view this article both online on a monitor and compare with a printed version of this same article. Furthermore, to evaluate colours for orienteering maps they must be viewed under light as close as possible to sunlight in nature (technically, Illuminant C). One should not compare the map straight off the home printer with the IOF swatch standing under a bluish fluorescent light.

Suggestions

It is unrealistic to expect anyone to define a colour coding system for orienteering that will be recognisable by all 3 classes of persons with colour vision defects, or even the most severe form of even the commoner defects. As tritans are very rare, or have eye disease that would of itself reduce vision (probably to the point that fine detail on maps would be unreadable), we suggest that the IOF should only consider avoiding confusions for Protanomals and Deuteranomals (those confused by the pastel shades).

Geometric coding that makes the colouring somewhat redundant should also be pursued. E.g. a brown cross and a green cross should be further differentiated as four star/six star and perhaps also be different sizes as suggested by others. Technically, there are other ways of encoding to make colour relatively redundant, such as cross hatching or patterning, but because of the small patches of colour so common on an orienteering map, these may become uninterpretable and hence unsuitable. Use of black outlines for one shade of colour might also be feasible.

A specialist in the field of colour vision should be involved in finalising the colour codes for orienteering in consultation with experienced orienteers and map makers. The cost involved would be much more likely to make orienteering more satisfying and viable for a further 4-5% of males, especially if they were educated regarding the notion that orienteering maps have been made with the more common colour defects in mind and are 'colour vision friendly'.

Footnotes

A scientific analysis of the failure of the IOF colour swatch to meet the needs of colour defective orienteers has been published: *Orienteers with poor colour vision require more than cunning running.* Long JA, Junghans BM. (*Clin Exp Optom* 2008; 91: 6: 515–523 or DOI:10.1111/j.1444-0938.2008.00294.x)

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