COLOUR BLINDNESS AND SCIENCE – 50 SHADES OF MUDDY GREEN INTERSPERCED WITH BLUES AND YELLOWS

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ABSTRACT

Colour blindness or colour vision deficiency (CVD) is the most common genetic disorder in humans affecting 250 million worldwide. About 8% of males have colour vision deficiency, i.e. 1 in 12 boys in schools. Despite its prevalence many teachers do not realise that it is more than 'getting colours mixed up'; it is a problem with distinguishing colours across the spectrum. This can impact on the engagement, understanding, and attainment of a pupil. Without correct diagnosis at an early age a child's motivation will be seriously affected.

INTRODUCTION

Colour, something we take for granted, is often a far more complex phenomenon that we realise. There are several experiments which can demonstrate this. Our perception if affected by many factors including background colours, previous exposure of the eye, and of course the physiology of our eyes.

Teachers are aware of that "colour blindness" is a problem for some students, but rarely have any training in dealing with the issues, rarely know who is colour blind in a class, and therefore rarely make any adjustments to lessons. 40 to 50 years ago when some of the research was carried out, often quoted to justify inaction by authorities, the world was a very different place, white chalk on a black board, black and white TV, and textbooks with little colour. However the 21st century children are brought up in a very different environment full of colour.

There is little consistency across Europe in either assessment of CVD or strategies to deal with it, particularly in schools. Children and parents are often unaware that they are colour blind, and many teachers do not have a clear understanding of the special needs of colour blind children. Hence pupils can be severely disadvantaged and incorrectly diagnosed as being inattentive, underperforming, or requiring other types of special education needs support.

There is very little information readily available as to how best to deal with this issue.

WHAT ARE THE DIFFERENT TYPES OF COLOUR VISION DEFICIENCY?

Our colour sensation is determined by the three different cones in our retinas, commonly called the blue, green and red cones. However this is a slight misnomer, as each cone is sensitive to a wider range of wavelengths, as will be understood from Fig.1.

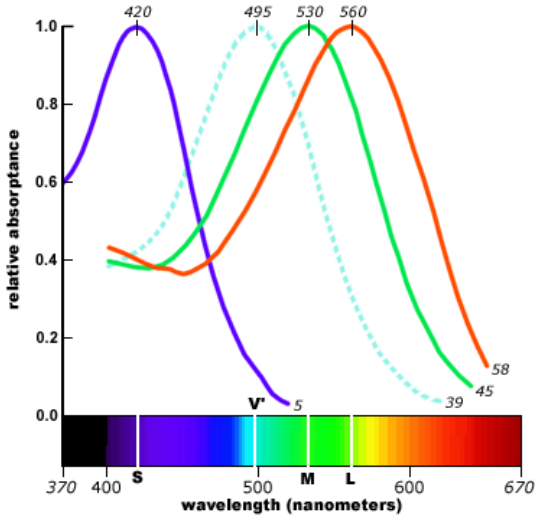

Fig.1. Diagram showing sensitivity of the three cones in the retina

The technical terms are as follows:

- *Trichromacy* describes 'normal' vision which is the 3 cones working together.

Those with Colour Vision Deficiency may suffer from

- *Protanopia* which is "Red" cone deficiency
- *Deuteranopia* which is "Green" cone deficiency
- *Tritanopia* which is "Blue" cone deficiency

Often the first two are groups together simply as "red/green" colourblind as the effects can be perceived as quite similar, as can be seen by looking at the computer generated simulations.

Birds and animals have visions which differ from what we regard as "normal human vision". Many mammals are what we would call "colour blind". Dogs for example work with only two different cones. Surprisingly, to many, a bull does not "see red" so is attracted to the toreador's cloak by its movement rather than its colour.

Thankfully, modern technology enables us to simulate what someone who suffers from CVD may see when confronted with different colours (Fig.2.).

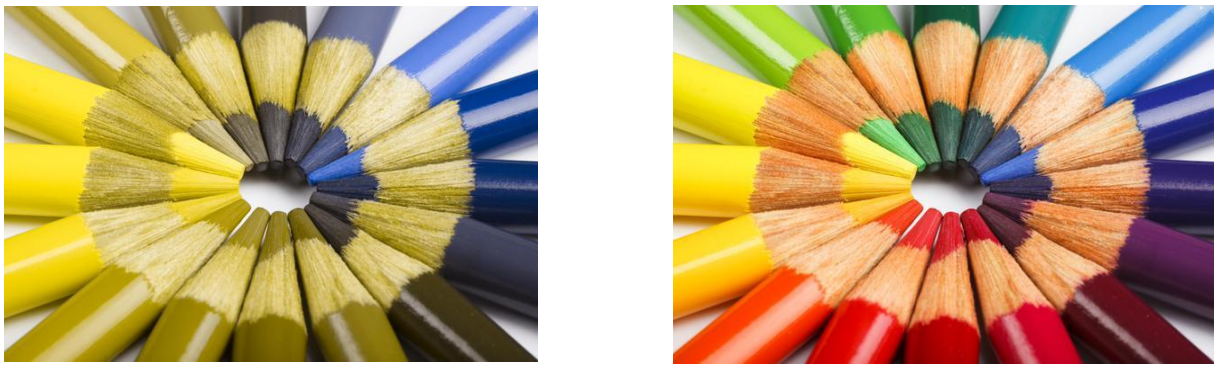

Fig.2. Coloured pencils as seen by someone with deuteranopia (left) and with normal vision (right), from Colour Blindness Awareness Association simulation by "vischeck" [1].

The effect is often hidden of course because a child has always been taught that that "muddy green" he sees is called "red" and so will call out "red" when asked. In fact the vast majority of children with CVD leave primary school without realising, and a staggering 50% leave secondary school in a similar state of ignorance. Even if they are capable of many tasks, those tasks may be much more difficult than for someone with normal vision, or even impossible. There are many tales of adults who have little colour sense when it comes to choosing clothes etc., and it is quite likely that some of these have CVD but are undiagnosed.

Two 17 year-old Dutch schoolboys were given a holiday job to pick tomatoes, but sadly one lost his job after one morning. He hadn't realise he was "colour blind" and did not distinguish between green unripe, and red ripe tomatoes:

Fig.3. Green and red tomatoes as seen in normal vision (left) and with deuteranopia (right), simulation by "vischeck" [1].

EXAMPLES IN THE SCIENCE CURRICULUM

Where colour is a factor, there may be issues for some children in a class. Remember 1 in 12 boys suffers from some form of CVD, that is one in every mixed class of 30 pupils (the condition is much rarer in girls, 1 in 200, but nevertheless likely to be at least one in every school). The degree of severity varies considerably child to child which make diagnosis more difficult. However it is estimated at 25% of those with CVD have it in its severest form, i.e. a missing cone type, whereas others may simply have a shortage in the balance of cones.

So as teachers as a first step we should watch out for students who have difficulty identifying species, using pH and other colour tests, or identifying colours of the spectrum. Apart from using CVD friendly colours, we could do a great service by alerting someone to a problem they have but which goes unrecognised.

Many physics teachers in the UK recognise that the colour coding on wires was changed several years ago to enable recognition of the different wires to be more reliably done by everyone. The example below shows just how effective this has been:

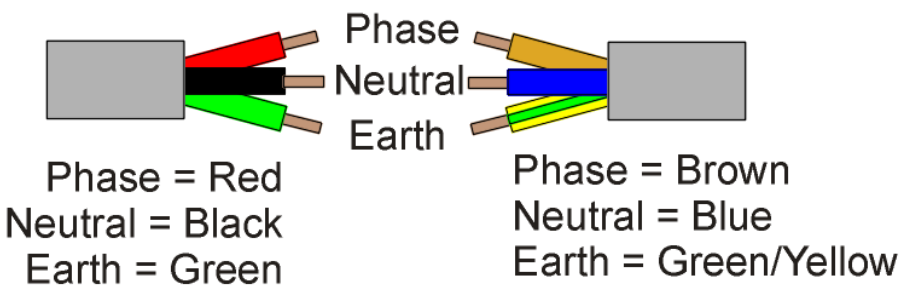

Fig.4. Electric wiring in the UK, before and after the change (NORMAL VISION)

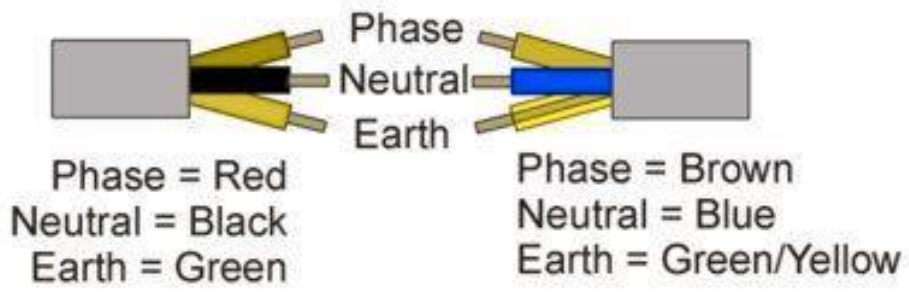

Fig.5. Electric wiring before and after the change simulated for *deuteranopia*

It is clear how easy it would have been before the change to confuse the Phase or Live wire with the Earth (as illustrated by Fig.6, too).

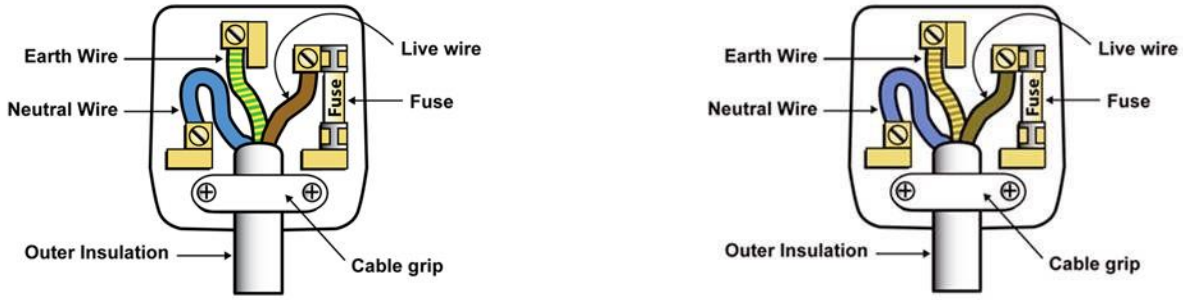

Fig.6. Wires in plugs, normal vision (left) and deuteranopia (right).

Fig.7. illustrates the difficulty experienced when reading a pH test. The diagram illustrates a liquid as seen by a CVD student and his pH test paper to compare with the liquid. Not an easy task... although it must be said that the majority of CVD students will have a heightened sense of the minor differences in shading that those with normal vision may not spot.

Fig.7. Testing for pH value, a *deuteranopia* student's view

This all presents interesting challenges not just for the student but also for the teacher. How for example should a physics teacher mark a CVD student's description of a spectrum from a prism, in which he/she genuinely only sees two colours. Should he mark as correct the division into two colours, or encourage the students to mark in his book different colours even though he/she doesn't see them? Figures 8 and 9 illustrate this. Note that the student labels the muddy yellow green as red… which of course some of it is!

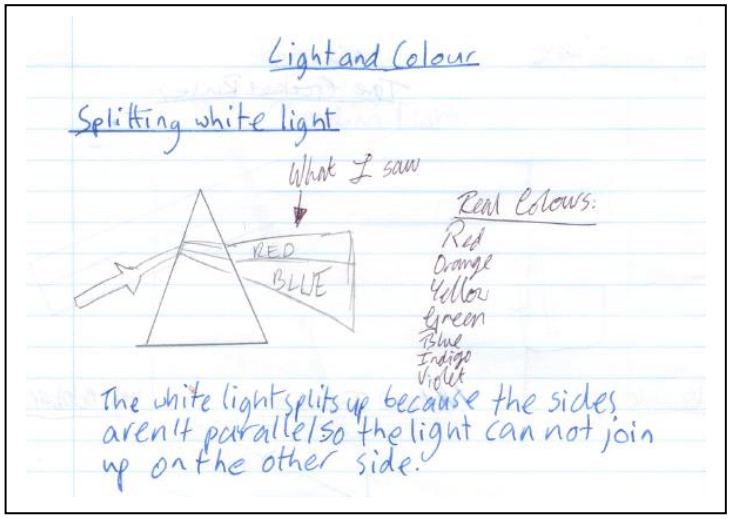

Fig.8. A page from a student's notebook. Is making a student record what he doesn't see educational dishonesty?

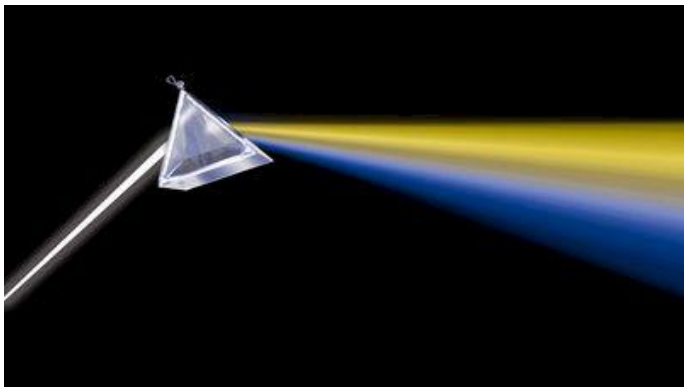

Fig.9. Spectrum as seen by someone with protanopia (red blind)

Interestingly the student in Figure 8 labels what we see as dull yellow/muddy green (in Fig.9.) as "red" presumably because he has always been taught that that colour is red.

The danger is that a teacher may diagnose the student's difficulties as what he or she perceives to be a silly mistake, laziness, lack of ability, lack of effort or inattentiveness rather than offering the necessary support. Students may become frustrated, and consequently disruptive. Teachers should therefore be alert to possible triggers – any colour confusion – that could help them identify that a students may have CVD that can then be easily tested.

Areas which may cause problems for students with a degree of CVD:

- Reading litmus paper accurately
- Undertaking chemical titrations in practical chemistry
- Identification of metals by the colour of the flame produced when the metal is burnt
- Accurately reading stained slides under a microscope
- Carrying out dissections in biology
- Identification of species of plants or insects correctly
- Fully understanding coloured diagrams in textbooks, particularly in biology, nature
- Use of prisms in physics
- Wiring of plugs in electricity, etc.

HOW TO HELP STUDENTS WITH CVD

Being aware of their challenges is the first step, but also the following strategies are helpful:

- Use Natural light
- **Secondary** indicators, e.g. signs on labels, or underline words
- Use yellow, blue and white for contrast in labels or charts, not green and red
- Have a sympathetic students as a Colour buddy
- Make clear boundary between colours
- Us a set of labelled pencils to indicate true colours
- Use large objects, held apart, when demonstrating if possible
- Use contrasts, e.g. red on a white background but not red and green together on a white background

Photographs may be checked using the simulation programme "Vischeck" [1]:
http://www.vischeck.com/vischeck/vischeckImage.php

The teacher simply needs to check any photographs used against the type of CVD. An even more useful app to help teachers see how difficult it may be is "iDaltonizer", which enables a teacher, on his phone, to see just what the students may see. I would recommend that all teachers download this free app.

It does seem that companies are beginning to develop products that will aid someone with CVD too. Spectral Edge, for example is able to help someone produce enhanced images by EYETEC technology. These emphasis slight contrasts between the colours of different objects.

A close friend has made with her son who suffers from *protanopia*, a short video which shows how he sees the world [2],
"Colour Blind Awareness #1ineveryclassroom Rainbow Song".

Further information can be obtained from the colour blind awareness organisation [3]. @colourblindorg (on Twitter).

I am grateful to Kathryn Albany Ward of the colour blind awareness group, who has provided much detail for this seminar and permission for photographs.

I would be very interested to hear of science teacher's experience in this field, either with students who have CVD or if they themselves have this challenge.

The author also has due to be published this year (2016) two extensive articles on CVD one in the International Journal of the Institute of Physics, Physics Education, and the other in the European Journal Science in School (publication dates are not yet known).

REFERENCES

1. http://www.vischeck.com/vischeck/vischeckImage.php
2. http://www.youtube.com/watch?v=l5OYL3Kw8L8
3. http://www.colourblindawareness.org