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Regular Wear of Coloured Glasses Improved the Symptoms of Colour Vision Deficiency

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Abstract: *Colour vision deficiency is an inherited genetic disorder. In the 21st century, where good colour vision has become particularly important, several companies manufacture and distribute glasses correcting colour vision deficiency (Chromagén, Colorlite, Colormax, Color Wiev, Enchroma). According to our current understanding, the colour vision improving effect of such glasses only lasts as long as they are actually worn by the patient. However, a patient with severe deuteranopia, who had been wearing the corrective glasses by Colorlite reported improved colour vision even when not wearing the glasses. This patient asked me to examine his colour vision to verify his claim. The patient's colour vision was tested using 4 different methods and indeed a significant improvement could be observed. As a result of regularly wearing the corrective glasses, the patient showed improved colour vision even when not wearing them and his deuteranopia turned into mild deuteranomaly. The significant improvement was probably the result of a learning process. Further experiments are recommended to study the correction of colour vision deficiency by learning.*

Keywords: *Colour vision deficiency, Anomaloscope, Ishihara test, Colorlite test, D15 test*

1. Introduction. Colour vision deficiency

Colour vision deficiency is an inherited genetic disorder. The ratio of people with colour vision deficiency within the population is lower in uncivilised, natural habitats and higher in densely populated, civilised environments (Fig. 1). The reason behind this is probably natural selection as in an artificial environment, proper colour vision is not essential for survival (Fletcher,Voke 1985).

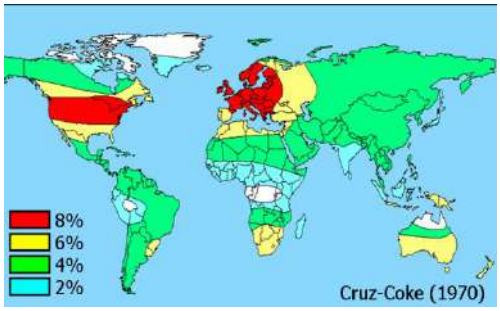

Fig. 1. Frequency of colour vision deficiency in global comparison

In Europe and the middle part of North America, 8% and 0.5% of the male and the female populations have colour vision deficiency, respectively. The remarkable difference between the genders is due to women having two X chromosomes, while men have one X and one Y chromosome. The genes responsible for colour vision deficiency are on the X chromosome (Gegenfurtner, Sharpe 1999). When a woman has one faulty X chromosome, the other one can still provide for proper colour vision.

The data illustrated by Fig. 1 describe the most common form of colour vision deficiency i.e. green-red colour blindness. However, many other forms are known. The reason for this diversity is physiological. Colours are perceived by three different perception units known as receptors (Gegenfurtner, Sharpe 1999). Their individual faults at various levels result in different forms of colour vision deficiency.

The colour sensitive receptors known as cones and being responsible for daylight vision have three types. These are the protos (sensitive to red hues), the deuteros (sensitive to green hues) and the tritos (sensitive to blue hues), known as long, middle and short wave sensitive receptors, respectively. Their spectral sensitivity is presented in Fig. 2. They are marked as L, M and S, while their spectral sensitivity as l(λ), m(λ) and s(λ), respectively.

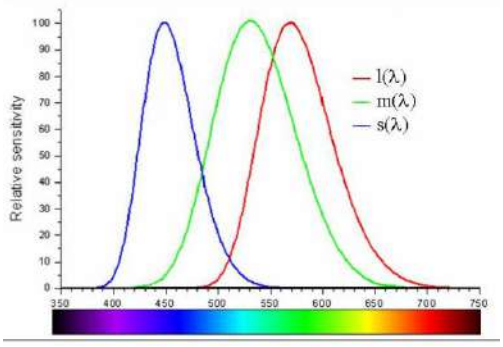

Fig. 2. Spectral sensitivity of colour sensitive receptors in people with normal colour vison

The most frequent colour vision deficiency types have two possible reasons. Either the sensitivity range of the protos receptors is too close to that of the deuteros (protanomaly), or the sensitivity range of the deuteros receptors is too close to that of the protos (deuteranomaly). When the two ranges shift closer to

each other by as little as 10-15 nm, it will result in a significant colour vision deficiency. In severe protanomaly and deuteranomaly, the distance between the ranges diminishes by as many as 20 to 25 nm. Such severe cases are known as protanopia and deuteranopia i.e. colour blindness. However, colour blindness is an inaccurate term. When the spectral ranges shift, all three receptors types are functional, only in an abnormal way. In true colour blindness, one or more receptor types are dysfunctional or even missing. Luckily, such severe disorders are very rare.

2. Symptoms of colour vision deficiency

The most important consequence of both types of colour vision deficiency discussed above is that the spectral sensitivity ranges of the protos and deuteros receptors shift closer to each other than in people with normal colour vision, thus they will overlap more. When the sensitivity ranges overlap, a single monochromatic light stimulus at a wave length in the overlapping section will stimulate both receptor types and result in the perception of mixed colours instead of pure colours.

As illustrated by Fig. 2, in the range between 440 nm and 640 nm, at least two types will be stimulated at the same time. The hue of the mixed colours will change continuously, depending on the level of sensitivity of the different receptors at the particular wavelength.

At wavelengths where both receptors are stimulated to the same extent (i.e. where the curves of spectral sensitivity intersect) a new colour, different from the basic colours will be perceived. For example, near 570 nm where the sensitivity curves of the red-sensitive protos and the green sensitive deuteros receptors intersect, the perceived colour will be yellow. Where the sensitivity curves of the blue-sensitive tritos and gree-sensitive deuteros receptors intersect, the perceived colour will be turquoise.

Mixed hues always appear to be lighter and paler than pure colours.

Hence, the symptoms of colour vision deficiency are as follows:

- As the sensitivity ranges of the different receptors types overlap more in people with colour vison deficiency than in those with normal colour vision, they perceive more colours as pale.
- Protos and deuteros receptors will be more or less equally stimulated in a rather broad range of the yellow colours, hence people with colour vision deficiency will perceive more colours as yellow than those with normal colour vision.
- Pale, yellowish hues differ only minimally, those with disrupted colour vision are only able to distinguish a reduced number of colours.
- Pale, yellowish hues do not create a contrast as sharp as pure colours, so in the case of colour vision deficiency, the resolution of the image captured by the eye will also be poor and patients will be able to differentiate fewer details.

3. Improving colour vision deficiency symptoms

Many attempts have been made to correct colour vision deficiency by means of various colour filters. Fletcher's book Defective Colour Vision, published in 1985, lists several successful trials (Fletcher, Voke 1985). Red and pink filters were proven to be particularly beneficial. Such filters were used in various attempts as glasses or contact lenses on one or both eyes. Others claim, however, that colour vision deficiency may not be corrected (CIE 2011). Nevertheless, in the 21st century, with the importance of good colour vision increasing, many companies are involved in manufacturing and distributing colour corrective glasses (Chromagén, Colorlite, Colormax, Color Wiev, Enchroma).

4. A surprising finding

As far as we know, coloured lenses are only able to correct colour vision as long as they are actually worn. The colour vision deficient eye and the corrective lens together form a colour perception system that resembles that of people with normal vision.

Nevertheless, a patient with severe deuteranopia who had been wearing Colorlite colour corrective glasses for 2 years reported a perceived improvement in his colour vision even when not wearing corrective glasses. He claimed his colour vision deficiency had been gone altogether. He asked me to test his colour vision to verify his claim.

His vision was checked then by means of 4 different methods and indeed a significant improvement could be shown.

1. Instruments and measuring methods

4.1. Anomaloscopy

The tests were conducted by means of an Oculus HMC anomaloscope. (Type: 47700, Serial number: SN 2411 9901, Year of manufacture: 1998). In accordance with the standard DIN 6160, the anomaloscope uses 3 monochromatic light sources to test colour vision, red, green and orange; 662 nm, 549 nm and 589 nm, respectively (Birch 1993). The field of vision is divided into two halves, one a mixture of green and red colours and the other one orange. The tested person should set the mixing rate of red and green and the intensity of the orange light in a way that the two halves of the field of vision match in colour. The result of the test is given by the values set by the tested person (R-G and Y in the first table). From these, the severity of colour vision deficiency as well as its nature (protanomaly or deuteranomaly) may be established. People with

normal colour vision set the values at R-G=45 +/- 5 and Y=15 +/- 4.

4.2 Ishihara test

These tests were performed using an Ishihara book (Ishihara 2017). The pictures in the book, made up of dots, are printed in carefully mixed colours. The hue of the dots forming digits are somewhat different to that of the background dots. Those with good colour vision easily identify the numbers; however, people with deficient colour visions will not be able to do so. My patient was asked to identify 20 numbers in each test run.

4.3. Colorlite test

These tests were performed using the test book made by Colorlite Ltd. by means of a photographic technique (Colorlite 2018). The pictures used for the test are similar to those of the Ishiara test in being composed of dots, but the tested person should identify Landolt C symbols instead of numbers. The pictures are arranged in a reverse order of difficulty, the first one being the most difficult. The tested patients are requested to identify 3 series of figures, each of different colours regarding both the background and the symbol. In the R/G series, the Landolt C is composed of red dots while the background of green ones. This series indicates the severity of the colour vision deficiency. The P series detects the dysfunction of the protos receptors, while the D series that of the deuteros receptors. The colours of the P and D series vary along the confusion lines. The result of the test is the number recorded by the pictures i.e. an empirical number indicating the differences between colours. The higher the value, the worse is the result. The worst and best result in the R/G P and D series is 300 and 0 and 200 and 0, respectively.

4. D15 test

These tests were performed using the coloured plates manufactured by the French company Luneau Ophtalmologie (Luneau Ophtalmologie 1990). The test includes 15 plates in Munsell colours. The colours cover the entire spectrum in the order of the hues of the rainbow (Birch 1993). Plates of blue, green, yellow, orange, red and purple should be arranged in the order of their colours. Characteristics errors in the order formed by the patient indicate protanomaly, deuteranomaly, tritanomaly and monochromatic vision.

The anomaloscope provides some indications of the spectral sensitivity of cones at the wave lengths of the 3 measuring lights. Each one of the other 3 methods tests colour vision using painted surfaces. The delicate hues of painted colours elicit different colour perceptions in the tested patient. The results of the Ishihara, Colorlite and D15 tests give indications on the ability of the patient to discriminate and identify colours.

2. Discussion. Measured results

Measured results are summarised in Table 1.

The columns of the table show the values measured with and without wearing corrective glasses side by side. In the top and bottom sections of the columns, results from 2 years ago and those that were measured now are given, respectively, as taken from the 4 tests applied. Anomaloscopy data are always the results of sets of 3 adjustments. The anomaloscope may not be used on patients wearing corrective glasses, thus the relevant cells are left blank.

Relying on the analysis of the results, we may make the following conclusions:

- According to the anomaloscopy results from 2 years ago, the patient had severe deuteranopia at the beginning of the test period (first cell of Row 1 in the Table 1.).
- The current anomaloscopy results indicate the patient's deuteranopia did not change in the 2 years between the first and the second series of measurements. It means the inherited disorder resulting in colour vision deficiency was not changed by wearing corrective glasses for 2 years (first cell of Row 2. in the Table 1.).
- Measured data in the upper rows of the table indicate that the corrective glasses improve colour discrimination and colour identification immediately and significantly, once they are put on.
- Measured data in the left half of the table indicate that colour discrimination and colour identification were significantly improved by wearing the corrective glasses for 2 years.
- Measured data in the right hand side cells of the bottom rows indicate that the colour vision of the patient has improved significantly by wearing corrective glasses for 2 years and this improvement is measurable even when the patient does not wear the glasses. We may conclude that the colour vision deficiency of the tested person has shifted from deuteranopia to mild deuteranomaly.

Table 1. Measured results

	Appliance used	Without Colorlite glasses	Wearing Colorlite glasses
2 years earlier	Anomaloscope	R-G=8.7 Y=17.2	
	Ishihara test	18 wrong 2 correct (from 20)	1 wrong 19 correct (from 20)
	Colorlite test	R/G 280, P 20, D 200	R/G 60, P 40, D 80
	D15 test	Deuteranomaly	Normal
Now	Anomaloscope	R-G=8.4 Y=17.5	

	Ishihara test	3 wrong 17 correct (from 20)	0 wrong 20 correct (from 20)
	Colorlite test	R/G 40, P 40, D 60	R/G 40, P 30, D 20
	D15 test	Normal	Normal

Conclusion

As a result of regularly wearing corrective glasses for 2 years, the patient showed improved colour vision even when not wearing them. The colour vision deficiency of the tested person has shifted from deuteranopia to mild deuteranomaly. The described significant improvement was not the result of a beneficial change in the physiology of cones, but presumably that of a learning process. It is recommended to perform detailed studies on the possibilities of improving colour vision by learning.

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