Congenital red-green colour deficiency: study of the efficacy of commercial colour filters

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This study focuses on the effectiveness of passive aids, particularly coloured filters. Although companies have toned down their claims in the face of mounting scientific evidence, they still stand by the effectiveness of their products. This study evaluates the long-term adaptation of EnChroma, Pilestone and Colorlite filters in different CVD subjects using multiple colour vision tests. The results indicate that these filters alter colour discrimination, with a trade-off between red-green and yellow-blue discrimination. The primary inference of this inquiry aligns with established scientific data: coloured filters provide minimal contrast enhancement for certain colour stimuli, but with a likely downside of diminished information for other colour stimuli. Although companies claim that long-term chromatic adaptation is crucial for the filter's effectiveness, this study concludes that such filters do not offer a solution for individuals with CVD seeking normal colour vision.

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Introduction

Around 8% of Caucasian males and 0.5% of females have congenital red-green colour vision deficiency (CVD) [1]. People with CVD typically possess weaker colour discrimination abilities compared to those with normal colour vision [2-3], which can lead to trouble executing daily activities and preclude them from specific professions [4]. This led to extensive research into aids for CVD [5]. Passive aids, such as colour filters, and active aids, such as smart glasses or recolouring algorithms, are broad categories of such aids.

In this paper, we examine the effectiveness of passive aids in improving colour contrast for CVD. Various companies, including EnChroma, VINO, Pilestone, Colorlite, and others, have introduced coloured filters in spectacles or contact lenses as a means to address this issue. However, it should be noted that a considerable portion of the improvement can be attributed to adjustments in luminance contrast [6]. This phenomenon explains why passive aids can in some cases enable people with dichromatic vision to successfully complete the Ishihara test or to discriminate between two colours in a scene that they would perceive as identical without the aid of a filter. However, there is considerable evidence that these aids do not in any way make the vision of people with CVD more like normal colour vision. Furthermore, they do not universally improve the observer's ability to discriminate between colours [7-11]. Some passive aids aim to be more individualised, allowing the user to choose from a range of colour filters the one they prefer or the one that gives better results on certain CVD screening tests [12].

According to abundant and compelling scientific evidence [13-16], using a coloured filter cannot make the vision of individuals with CVD equivalent to that of normal trichromatic individuals. Additionally, applying a spectrally selective external filter that is similar to altering the illuminant cannot expand the colour gamut. In particular, selective narrow-band or cutoff filters that increase chromatic and/or luminance contrast in some wavebands must take away even more contrast in other wavebands. Furthermore, although these filters are capable of altering the overall relative sensitivities of cone types, they are unable to modify their spectral responsivity shapes. As a result, CVD observers cannot attain typical trichromatic vision using these devices.

Some companies have moderated their claims in recent years due to numerous scientific papers assessing the effectiveness through various experiments. Most of them have stopped asserting the provision of normal colour vision for CVD subjects, as they did initially. Instead, they now assert the ability to enhance CVD's colour vision to some extent. However, they persist in their refusal to accept the widely accepted scientific consensus that the studies carried out by scientists are accurate, well-designed, and properly assess the claimed enhancement of colour vision. They further assert that the efficacy of the filters needs to be evaluated after long-term usage to account for prolonged chromatic adaptation [17-18].

Discussion

Our evaluation considered the subjects wearing the glasses continuously for two weeks. During this period, we measured colour perception every two days using two colour vision tests: Farnworth-Munsell 100 [19] and the Color Assessment and Diagnosis (CAD) [20]. Prior to participating in the study, all subjects provided informed consent. The study was conducted in conformity with the Declaration of Helsinki, and the Ethics Committee of the University of Granada approved the protocol (2604/CEIH/2021). CVD participants were classified based on their discrimination outcomes attained via an OCULUS anomaloscope. The results obtained from the CVD participants were compared to those obtained from a control group with normal colour vision.

Different models of coloured filters, whose spectral transmittances are shown in Figure 1, from three different companies - EnChroma, Pilestone and Colorlite - were used in this study. The EnChroma models evaluated were the Cx1 and Cx1 DT, with a total of seven subjects, consisting of three protanopes and four deuteranopes. The Pilestone filters tested were TP-002, TP-025 and TP-037, with six subjects including one deuteranomalous, two protanomalous and three protanopes. Finally, the Colorlite models included D15, D30, P15 and P30 and were tested on 13 subjects including 4 deuteranopes, 1 deuteranomalous, 3 protanomalous and 5 protanopes.

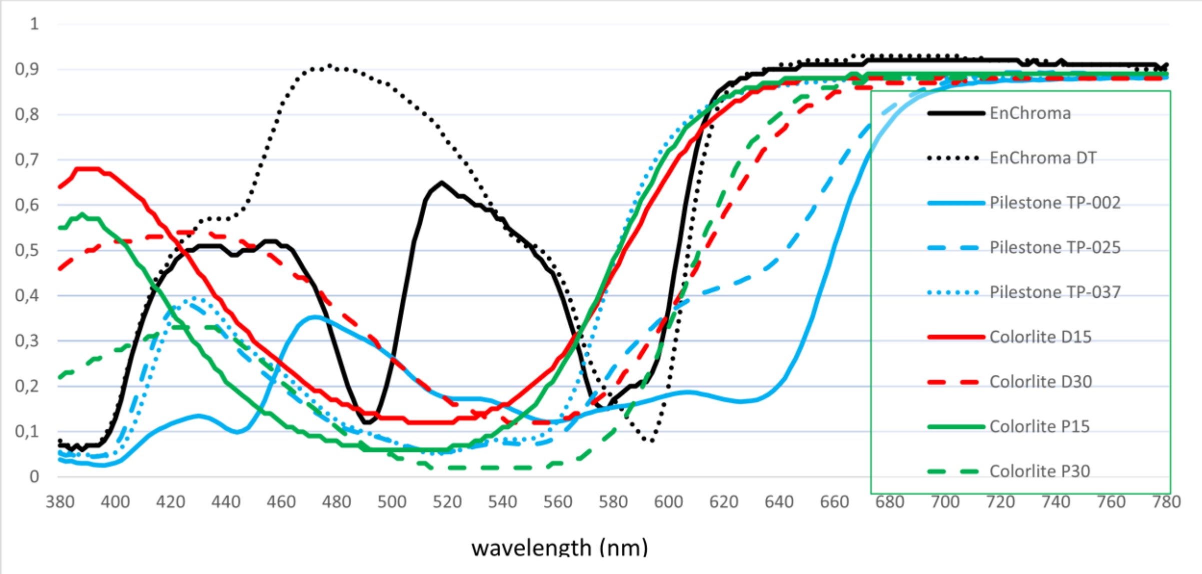

Figure 1: Tools used for the environmental colour imagery survey.

The Pilestone filters had mixed effects on colour discrimination. The TP-037 filter showed a slight improvement in red-green discrimination but caused confusion in yellow-blue colours. On the other hand, the TP-002 filter worsened discrimination for all colours, and the TP-025 filter also reduced the ability to differentiate most colours, although less severely than TP-002. These findings suggest that Pilestone filters may be more effective for mild deficiencies than severe ones. Additionally, our study supported previous research [6-8] showing that wearing coloured filters shifted the confusion axis for protanopes in a clockwise direction and for deutans in a counterclockwise direction. Notably, none of the participants wearing Pilestone filters passed the Ishihara test, and their FM 100 results did not reach the Total Error Score of individuals with normal vision.

The Colorlite filters lead to a decrease in FM-100 test scores for all individuals, regardless of their CVD type and filter model. With regard to CAD, a slight reduction in the size of the discrimination ellipse is seen for anomalous trichromats. Additionally, a shift of the ellipse for protanopes from protan to deutan is also observed.

For EnChroma filters, it has been noted that during an FM-100 test, protan individuals make more mistakes without spectacles than with them. The opposite holds for deutan individuals. The CAD test results for protan individuals indicate a gradual enlargement in discrimination ellipse. On the other hand, deutan participants displayed a reduction in the semi-major axis of their discrimination ellipse, accompanied by rotation and an increase in the Y-B threshold.

In summary, the CAD test showed that some filters provided a minor improvement in distinguishing red-green colours, while simultaneously causing confusion in previously unaffected yellow-blue colours. Additionally, other filters resulted in a slight alteration of the orientation of ellipses. Specifically, the ellipses shifted from a protan to deutan orientation, which predominantly affected dichromats, namely protanopes. Any slight improvement in the FM-100 test, as compared to the initial day of filter use, might be credited to mere repetition-based learning as opposed to chromatic adaptation. The participants provided subjective feedback that corresponded with the crucial moments of the study, which occurred when they put on or took off the glasses, as these were the periods in which they experienced the greatest variation during the numerous examinations. Several participants have reported experiencing difficulties and discomfort, especially at home, because the colour of many everyday household objects they were already familiar with has changed.

Conclusions

The filter companies we analysed assert that long-term chromatic adaptation must be considered for a fair assessment, which our research accomplished. Our findings indicate that the filters alter contrast levels which may be advantageous or disadvantageous depending on the specific task at hand. The key finding, aligning with overwhelming scientific evidence, is that coloured filters can be valuable in generating partial increases in contrast for certain stimuli, while sacrificing information for differing colour stimuli. The specific outcomes are also contingent upon the type and severity of the observer's CVD.

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