Spectrum Shifting: An Effective Technique to Aid Colour Differentiation for Colour Blind Users

Abstract

Colour Vision Deficiency (CVD) also known as colour blindness affects many people in their day-to-day lives, reducing their ability to distinguish certain colours. The predominant types of CVD are red-green CVD and blue-yellow CVD. We introduce colour spectrum shifting to aid CVD users, enhancing their colour differentiation by making better use of the existing range of colours they can perceive. Spectrum shifting is demonstrated within ASTER, an iOS phone app applying real-time image processing to the live camera feed. Using ASTER, users with CVD can now correctly identify all the numbers in a standardised Ishihara test and they also report it effective in everyday use.

Keywords: colour vision deficency, colour spectrum shift, app development, real-time image processing

1 Introduction

Approximately 300 million individuals globally experience CVD, the most prevalent types of CVD are red-green (protan and deutan) and blue-yellow (tritan). A standard way to assess whether an individual has red-green CVD is the Ishihara test, shown in Figure 2. The test assesses whether someone can distinguish between different hues to identify an embedded pattern or number. When tested colour spectrum shifting completely restored a CVD user's ability to identify the numbers correctly.

We introduce colour spectrum shifting, a technique that allows people with colour vision deficiency (CVD) to distinguish different colours by taking full advantage of the existing colours they can perceive. This is accomplished by eliminating the indiscernible colours in the colour spectrum and using colour interpolation to fill in the gaps with colours that they can distinguish. This technique is demonstrated in an iOS app, allowing users to utilise colour spectrum shifting on both a real-time camera feed and pre-existing images.

2 Related Work

Several technologies can currently aid those with CVD and minimise its effects on their lives. Some existing solutions are colour blindness correcting glasses and mobile apps.

EnChroma glasses filter light to enhance the contrast between red and green light [1]. However, they are only suitable for red-green CVD users. A study also showed that the glasses will not allow the user to view new colours. Instead, they enable the user to view the same colours differently [2]. Previously, Langoltz et al proposed ChromaGlasses which presented a way to correct CVD by using Epson Moverio active glasses and real-time pixel processing to augment the colours of objects [3].

Since a person with full colour vision cannot otherwise appreciate the experience of people with CVD. We used the established "CVSimulator" [4] to evaluate the effects of colour spectrum shifting from the perspective of a person with CVD. We also used the app to confirm the effectiveness of the technique before formal user evaluations.

3 Method and Implementation

Spectrum shifting is implemented by creating colour transfer functions, calibrated for each different type of CVD. These conversions determine the required spectral translation for each colour that the user cannot distinguish into another that they can, while best preserving existing colour perception. The new spectrums are constructed by observing the CVD-simulated colour spectrums and identifying sections without distinct differences.

The leftmost spectrum of Figure 1 shows the shifted spectrum designed for people with Protantopia, it removes the red section of the spectrum by removing the red colours and stretching the purple hue to the end of the spectrum. The fuchsia hue is shifted to the start of the spectrum to fill in the gaps. The yellow, green and blue sections are kept the same to minimise changes.

The middle spectrum of Figure 1 presents the shifted spectrum tailored for people with Deuteranopia. This spectrum was derived from the spectrum for Protanopia, modified to enhance the differentiation between fuchsia and green as these colours are harder to distinguish with Deuteranopia.

The rightmost spectrum of Figure 1 is the shifted spectrum created for people with Tritanopia. The red and yellow hues have been stretched to replace half of the green hue. The green hue is then used to stretch across the blue. This eliminates the majority of the blue section by translating the blue hue to cyan or green.

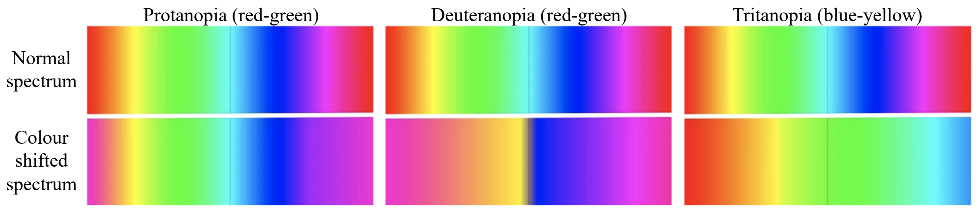

Fig. 1 Shifted Colour Spectrum for Protanopia (left), Shifted Colour Spectrum for Deuteranopia (middle), Shifted Colour Spectrum for Tritanopia (right)

4 Effect of Colour Spectrum Shifting

Figure 2 presents one representative Ishihara plate in the first column. In the second and fourth columns, a Protanopia and Deuteranopia simulator respectively have been applied to the plate. The third and fifth columns show the effect of using the colour shift feature on the original plate, the corresponding CVD filter is applied back onto the plate to simulate the CVD condition using "CVSimulator.

As seen in Figure 2, there is a distinct difference between the Ishihara plates without and with the spectrum shift from the perspective of CVD users, demonstrating the effectiveness of colour spectrum shifting when completing the Ishihara test.

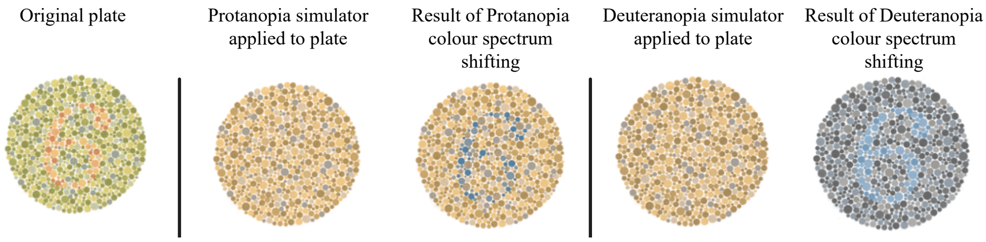

Fig. 2 Effect of Colour Spectrum Shifting on One Ishihara Plate

5 Delivery - The ASTER iPhone app

An iOS app called ASTER (Advanced Spectrum Transformation and Enhanced Recognition) has been developed to incorporate colour recognition features along with colour spectrum shifting. Colour spectrum shifting is implemented, with an integrated tool to identify the original colour of objects prior to shifting. This colour identifier includes a movable pointer for users to select a pixel to identify its colour in verbally.

ASTER has three main features, colour spectrum shifting, colour identification and colour highlighting. Figure 3 shows the interface for different features in ASTER. Colour identification identifies colours by displaying the colour name of the RGB code of a pixel. Colour highlighting will emphasise a specified colour (red in this case) by either desaturating all other colours (desaturation mode) or applying patterns and adding textures to the specified colour (hatching mode).

6 Evaluation

To evaluate the effectiveness of colour spectrum shifting, a user study was performed. 15 participants aged between 18 and 34 with CVD (M: 14, F: 1) were recruited. The study received a favourable ethical opinion from [redacted].

Participants were asked to take an Ishihara test both without and then with the aid of the colour shifting tool and then answered a questionnaire about their experience of using the ASTER app.

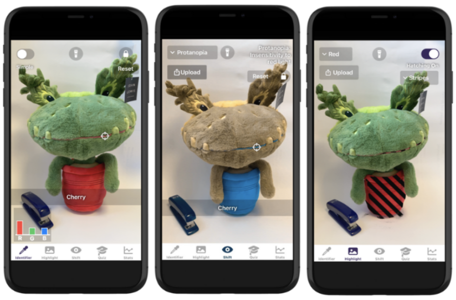

Fig. 3 Colour identification (left) shows the name of the colour under the pointer, the middle image shows the effect of spectrum shifting. Colour highlighting (right) emphasises a colour range (in this case, red) by applying patterns or textures over the specified colours.

In summary, every user correctly identified the numbers in the Ishihara plates with colour spectrum shifting applied, which they could not do without it. 67% of participants with CVD reported that the shifted colours were not distracting or unnatural on first use. 80% of participants also found the feature 'easy to use' and were able to identify the filter suitable for their type of CVD. One user commented that using the colour spectrum shifting "for the Ishihara tests felt like magic" and another user mentioned that even though they could view the number using another filter, using the filter tailored to their type of CVD was much clearer.

7 Summary and Conclusions

In conclusion, user evaluation confirmed that CVD users were able to clearly and correctly recognise all the numbers in the Ishihara test with the help of ASTER. By keeping some sections of the colour spectrum constant, the colour spectrum shifting was able to provide a more natural view. When using ASTER, it was clear that CVD individuals' ability to distinguish the colours of different everyday objects markedly improved. We believe that ASTER represents a step change in support of CVD users.

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