Using Augmented Reality to Help People with CVD Identify Colours Through Temporal Luminance Displacement

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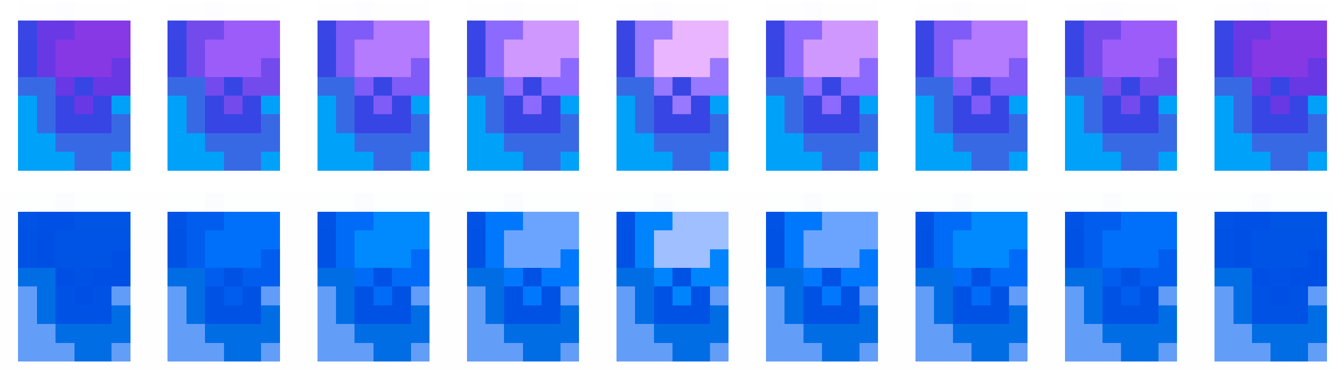

Figure 1: Temporal based increase in luminance being used to identify the colour purple, at increments of 0.25 seconds over a two second duration. Top row features blue and purple as they appear with trichromatic vision. Bottom row displays a simulation of how the luminance displacement might appear to a user with Protanopia.

Abstract

Colour plays an important role communicating information in the world around us. However, people with Colour Vision Deficiency (CVD) face challenges accessing this information because they perceive a reduced gamut of colours, resulting in difficulty differentiating and identifying certain colours. To help people with CVD, we propose a novel technique to convey invisible colour information through the use of temporal luminance displacement via video pass-through on a head-mounted display.

CCS Concepts

• **Human-centered computing** → **Accessibility technologies**; **Mixed / augmented reality**.

Keywords

Colour Vision Deficiency, Colour Identification

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1 Introduction

Colour plays an important role within our daily lives. We use it to communicate information and evaluate our surroundings. For a majority of the general population this perception involves trichromatic vision, meaning they perceive colour through the utilization of long, medium, and short wavelength cones found within the eye [6]. However, a subset of the general population does not perceive colour through trichromatic vision, but instead perceives colour through dichromatic or monochromatic vision. This is due to the absence of one or more of the long, medium, or short wavelength cones in the eye. As a result, these individuals perceive colour differently compared to their trichromatic peers. This difference manifests as specific colours appearing similar to each other, which causes difficulty identifying / differentiating between said colours. This is what is known as Colour Vision Deficiency (CVD), also known colloquially as colour blindness [1].

The ambiguity caused by this difference in perception can cause difficulty for individuals with CVD as colour is often used to communicate information. For example, the colours red and green are often used to communicate positive or negative outcomes. The colour green is often used to indicate success or acceptance, and red is often used to communicate warnings or failure. This is problematic as red and green are perceived as similar by those with protanopia/protanomaly and deuteranopia/deuteranomaly (red-green colour blindness). This prompts the question what technologies can we develop to better aide individuals with CVD in navigating ambiguity related to colour perception.

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2 Related Work

The creation of support technologies for individuals with CVD has long been a topic of interest within the field of HCI. This work has included the development of technologies involving Head Mounted Displays (HMDs) and augmented-reality, such as the work of Tanuwidjaja et al. [7] and Langlotz et al.[5], which both utilized optical see-through head-mounted displays (OSTHMDs) to convey information to the user.

Tanuwidjaja et al. [7] developed multiple tools using the augmented reality functionality of the google glass OSTHMD. These tools entailed: a colour highlighting mode, a contrast mode, a Daltonized recolouring mode, and an outlining mode indicating areas of difficult to decern colour. They then evaluated these tools through conducting user studies involving participants with CVD. In doing so they determined that participants found their tools most useful for verifying suspected colours. However, participants also identified several issues with the system. They found issues with the colour identification model regarding specific colours like browns and purples. They also found switching between modes to be cumbersome, as well as issues with latency due to hardware limitations [7].

Similar to this, Langlotz et al. [5] developed augmented reality glasses built off of the Epson Moverio BT-300 OSTHMD. On which they implemented multiple recolouring modes each intended to increase colour discernibility for individuals with CVD, as well as, multiple outlining modes each of which outlined colours difficult to identify for a user with CVD. With this tool their participants were able to successfully identify Ishihara plate tests at a much higher rate. However, they also encountered issues with latency due to hardware limitations [5].

While prior work has found some success utilizing recolouring tools in aiding colour discrimination, the work of Geddes et al. [3] found that this may not be a solution desired by individuals with CVD. As many individuals with CVD finding them to be intrusive or ugly, as well as, finding that they remove visual clues that would otherwise allow them to identify difficult colours correctly.

Other methods for aiding individuals with CVD have been created such as the work of Flatla et al. [2], in which they developed methods for isolating colours within or overlaying information over visuals for the purpose of aiding individuals with CVD in identifying difficult/ambiguous colours. To accomplish this, they developed a colour naming model based on the work of Heer and Stone [4], refining their colour naming dictionary down to a small number of colour names most relevant to conveying colour information [2].

3 Design

We have developed a potential approach for aiding individuals with CVD in colour identification. Our approach utilizes the video pass-through capabilities of the Meta Quest 3 along with the colour grading functionality of the Unity game engine combined with purpose built colour look up tables (CLUTs). We have created these CLUTs such that when applied in sequence they create a pulsating highlight effect through luminance displacement of a specified colour. These colours are identified using a colour naming model simplified from the work of Heer and Stone [4], using a method similar to that outlined by Flatla et al. [2].

For example, if a user wanted to identify all purple items within a given space, they would select the option to aid in identifying purple. After doing so they would then activate the temporal pulse. Over the next one second increment, all pixels identified as purple will begin to increase in luminance proportional to their colour name percentage of purple. At the end of the one second increment, the identified pixels will reach their maximum luminance displacement, after which they will then decrease in luminance over the next one second increment, at which point they will have returned back to their original colour. See Figure 1 for a visual representation.

While this creates a highlighting effect similar to the highlighting modes implemented by Tanuwidjaja et al. [7], our design iterates upon their approach in multiple ways, (1) our model is able to communicate ambiguity of colour name through scaling of luminance displacement, as the Heer and Stone model provides a colour name percentage for each colour instead of a binary classifier, (2) we utilize colour grading CLUTs to reduce processing overhead and latency similar to the approach used by Langlotz et al. [5], (3) in using video pass-through we are able to decrease luminance, an effect not possible when projecting an image onto a lens as was done by both Langlotz et al. and Tanuwidjaja et al. [5, 7].

4 Use Case

Our approach is intended to aid users with CVD, in identifying colours otherwise difficult to them, with minimal intervention/alteration to their vision, while also conveying colour ambiguity.

To showcase our approach we will be running our aid on a Meta Quest 3 paired to a computer connected to a display screen, so that viewers are not required to wear the device to experience it. This also mitigates the need for the device to be cleaned between each usage. Viewers will be able to physically manipulate the Meta Quest and its controllers and activate the colour identification pulse themselves. We will have coloured objects present for the viewers to engage with when using the aid. We also intend to implement a CVD simulation so that viewers without CVD can experience how the aid might work for a viewer with CVD.

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