Classifying user interface accessibility for colourblind users

Amaan Jamil[1] and Gyorgy Denes[1]
[1]The Perse School, Cambridge

CCS Concepts

• **Computing methodologies** → *Perception;* • **Human-centered computing** → *Accessibility systems and tools;*

1. Introduction

Colour vision deficiency (CVD, colourblindness) is the failure or decreased ability to distinguish between certain colours under normal illumination. There are approx. 300 million people with CVD, 1 in 12 men (8%) and 1 in 200 women (0.5%) [Cli23]. CVD is an X-linked genetic disorder with varying degrees of prevalence in different populations [FAAO22]. It affects an individual's ability to perform tasks in both personal and professional settings [TPT*04].

With displays utilising increasing colour gamuts, user interface (UI) designers rely on colour to convey key information to the user; e.g. green and red are often associated with 'yes' and 'no' respectively. Objects of the same colour satisfy the Gestalt principle of similarity, whereas different colours can help an object stand out or mark figure-ground articulation [Tod08]. However, these dimensions are reduced or lost to someone with CVD.

UI designers have taken various approaches to tackle the issue of CVD, including decreasing the aesthetics by using a reduced colour palette (high-contrast mode), integrating colour-blind awareness into the design process, relying on automatic post-processing enhancements (*daltonisation*) [SLF16].

The Web Content Accessibility Guidelines (WCAG) [wca18] outline some best practices for maintaining accessibility; however, it is uncertain to what extent current UIs follow these. In this work, we analyse a number of popular websites and software packages with a range of use cases to establish how much of their functionality is available to CVD users. To gain a strong understanding of how each industry manages CVD, we chose the most popular websites and software packages from prominent industries within the space such as Productivity, Education and SaaS. Specifically, we discuss relevant WCAG criteria, we simulate various types and severities of CVD on screenshots of UIs, analyse how much functionality is lost and compile our results into a rating of "UX experience and aesthetics kept" where there is a strong user experience and aesthetic similar to a non-CVD user would experience and to "core lost functionality" where the functionality central to the website or software package is inaccessible and unusable due to it's lack of accomm odation for CVD users.

2. Background

Human vision is generally understood to be trichromatic, with three types of retinal cone cells (L, M, and S) responding differently to wavelengths of light (Fig. 1). CVD can occur as a result of cone cells being absent, not working or having an abnormal response. Severe CVD occurs when two or three types of cone cells are absent (monochromacy, achromatopsia). Milder CVD occurs when one type of cone is absent (L: protanopia, M: deuteranopia, S: tritanopia), or all three are present, but one cell has an abnormal response (L: protanomaly, M: deuteranomaly, S: tritanomaly). This last type of CVD is the most frequent, with reduced ability to distinguish between greens and reds being the most prominent [MSM15] due to the spectral similarity of the M and L cones.

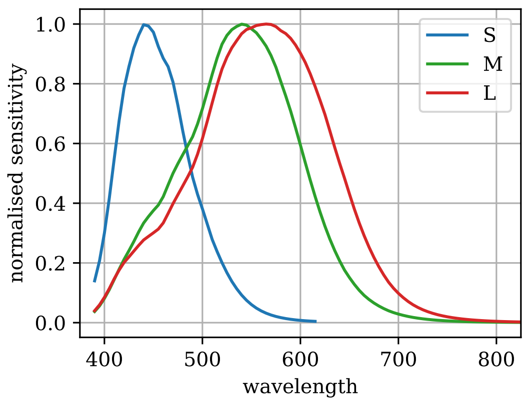

Figure 1: *Normalised spectral sensitivity of the three types of retinal cone cells as a function of light wavelength. Note the similarity of the M and L cones. Source: Stockman and Sharpe [SS00].*

3. Analysis

As a representative user study would need a high number of participants with varying CVD, we adopted a simulation-based approach, which is reproducible by people without CVD. Specifically, we first collated a dataset of 56 screenshots of 30 popular standalone software and websites, enabling colourblind modes and themes where available. Then, we used the CVD simulation by Machado et al. [MOF09, Smi18] to simulate 5 levels (20%, 40%, 60%, 80%, 100%) of protanomaly, deuteranomaly, and tritanomaly.

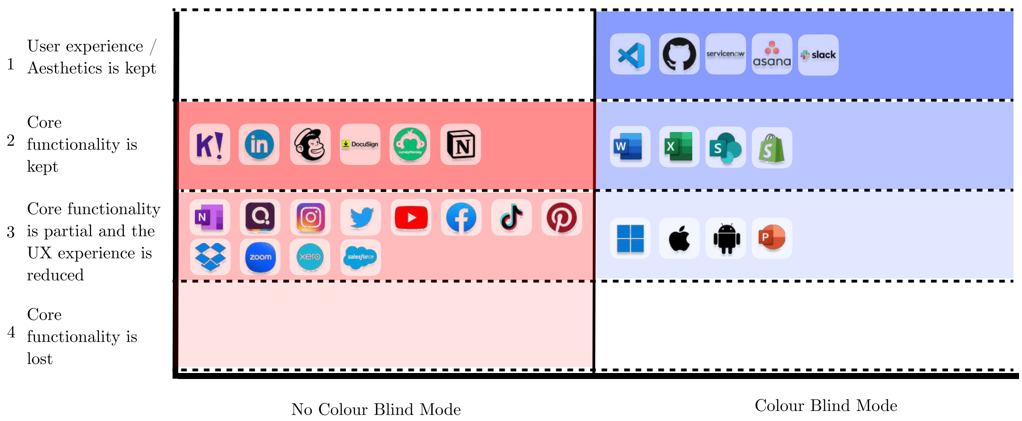

Table 1: *Tabular results of our user interface classification.*

The screenshots often contained too much information to be processed automatically, so the final classification was performed by the authors, observing the following criteria in WCAG 2.1 [wca18]:

- 1.4.1 Use of Color (Level A): encourages providing information conveyed via colour through other visual means
- 1.4.5 Images of Text (Level AA): encouraging text being used to convey information rather than images of text
- 1.4.11 Non-text Contrast (Level AA): visual presentation of UI components and graphical objects having a contrast ratio of at least 3:1
- 1.4.6 Contrast (Enhanced) (Level AAA): visual presentation of text and images of text has a contrast ratio of at least 7:1

During our initial investigation, we found that while text contrast (1.4.6) and non-text contrast (1.4.11) were often maintained in the CVD-simulated screenshots, neighbouring UI elements became harder to distinguish (Fig. 2). Hence, we computed CIE dE2000 colour differences [LCR01] between main UI components in the original and the CVD simulated screenshots to quantify distinguishability across elements. For some complex UIs with multiple coloured elements, this approach was not feasible and we applied subjective judgement. We also inspected the screenshots side-by-side to understand whether the aesthetics might be reduced. We then classified each UI into a table (Table 1).

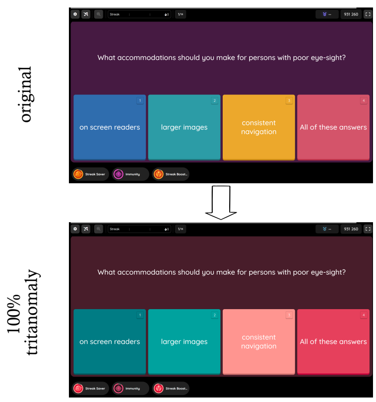

Figure 2: *Screenshot processed with simulated CVD simulation [MOF09]. Contrast across UI components can often be reduced.*

4. Discussion

While analysing UIs, we noticed that a key difference was whether the UI provided its own CVD theme (vs. the operating system's (OS's) reduced-palette high-contrast mode). We observed that UIs with dedicated CVD themes were more successful at meeting WCAG guidelines and maintaining aesthetics. We also found that while text alternatives for colour differences is a WCAG success criterion (1.4.1), not all existing UIs were compliant. All analysed UIs maintained the majority of their core functionalities. UIs without dedicated CVD themes complied with the OS's high-contrast mode, and we found that enabling high-contrast mode resulted in an overall improvement in text readability for all software in Category 3. While this helped to maintain core functionality, aesthetics (e.g. decorations) were often lost, and the improvements did not impact image and video elements. Perhaps an OS-level daltonisation approach would be more successful.

5. Conclusions and Future Work

We analysed a number of popular websites and software packages to establish how much of their functionality is available to CVD users. Specifically, we used existing techniques to simulate the effects of CVD on a number of screenshots and then manually classified each. In the future, we hope to investigate how the process could be automated, and calibrate our results with a subjective user study. We also hope to expand and release our dataset of screenshots.

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Proceedings published by Eurographics - The European Association for Computer Graphics.