ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THSH103

USING COLOR BLINDNESS SIMULATOR DURING USER INTERFACE DEVELOPMENT FOR ACCELERATOR CONTROL ROOM APPLICATIONS

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Abstract

For normally sighted developers it is hard to imagine how the user interface is going to look to a color blind person. Our purpose is to draw attention to people with color blindness and to consider their color vision. For that, this paper presents the integration of color blindness simulators into the development process of user interfaces. At the end we discuss the main contributing factors.

INTRODUCTION

Developing a user interface contains the usage of visual components in various colors for e.g. to separate areas of interaction, notification or to signal warnings and alarms. Developers with no color blindness or even of the knowledge of it cannot imagine how these people view their applications.

During the designing process of user interfaces we should try to reach as many people as possible who are able to use a desktop rich client or web applications. Our general aim as developer should be to abolish the barriers to operattions applications because people are afflicted with color blindness or in other ways disabled. To produce more effective visualizations, we need to devise techniques which help these people.

In this paper, our purpose is to draw attention to people with color blindness and to consider their color vision. Our approach is to give a short overview of color blindness. Then we investigate simple principles in choosing colors to improve our user interface design, afterwards we involve color blindness simulators into the development process. As a result of this work, we expect to offer improved control room applications for operators affected by color blindness.

COLOR BLINDNESS

Overview

Approximately 8% of all men and 0.5% of all women worldwide are affected by color blindness [1, 2]. That does not mean that they cannot see any colors. They are only unable to differentiate them. For that reason color blindness is also known as color vision deficiency (CVD).

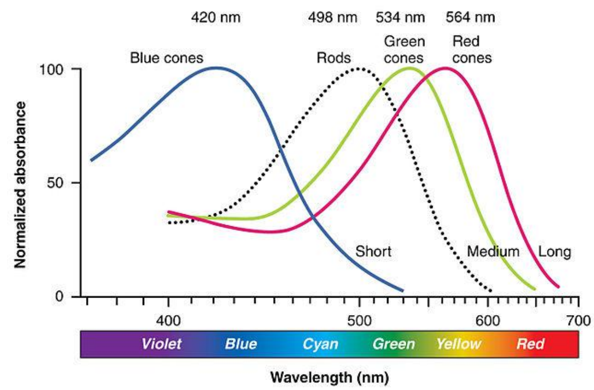

Figure 1: Wavelength of rods and cones [3].

Our human eye contains millions of light-sensitive cells called photoreceptors. Some are shaped like rods and some like cones. Rods are responsible for detecting brightness and are unable to distinguish different wavelengths. Cones on the other hand are sensitive to three certain wavelengths (see Table 1 and Figure 1). The mixture of those three different cone types generates our color vision. If any of these cone types is malfunctioning or missing, causes in color blindness (Figure 2) [4].

Table 1: Human Eye Cones and their Wavelength

wavelength	color	effect: missing/faulty cones
Short	Blue	Tritanopia/ Tritanomaly
Medium	Green	Deuteranopia/ Deuteranomaly
Large	Red	protanopia/ protanomaly

In most cases CVD is the result of defects in the genes. Unfortunately, people with color vision deficiency even do not know that or they are reluctant to admit it. And this has a significant impact on their private and business lives. [5-7]

There are three most common types [8]:

1. Red-Green: The most common types of color blindness - limited function of red or green cone
2. Blue-Yellow: rarer than red-green color blindness
3. Complete color blind: very rare - No cones exist.

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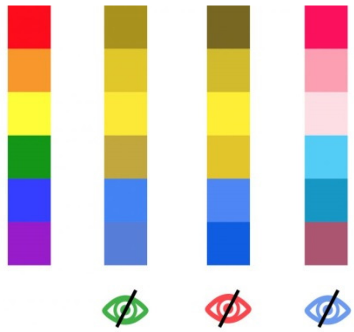

Figure 2: How the rainbow colors may look to people with CVD [9].

CVD Diagnostic

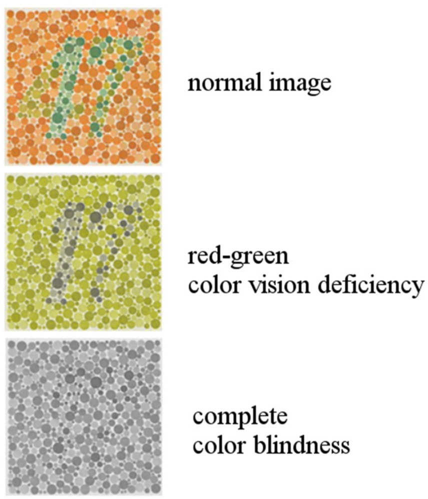

Figure 3: Simulation of color blindness [10].

Professionals use a variety of tests to diagnose color blindness [4, 8]. In Figure 3 an example of the commonly used Ishihara color vision test to identify red-green CVD is illustrated.

Support for People with CVD

Since medical techniques cannot solve color blindness, other correction methods have to be considered. People with red-green CVD may be able to use lenses that filter certain wavelengths of light [11]. In recent years many applications are provided that help people differentiate between colors. Some of these applications are listed in [12-14].

To help people with CVD in different areas in life, there is a large selection of research devoted to assisting these people. Some of them in the last few years are noted in [6, 15-21].

ACCESSIBILITY FOR USERS WITH COLOR VISION DEFICIENCY

For building applications accessible for people with CVD we do not need to be experts in color vision. We only need to reduce the visual disabilities of applications for these people. For that, we pay attention to design practices and simulations tools.

CVD Friendly Design Practices

Designers of webpages and graphical designers have a lot of experience on creating visualizations to reach many people. As a result of that, a set of 'selecting color' guidelines is offered [22-25]. After pointing out some advantageous techniques in control room applications, we advise taking action according to the following guidelines.

Avoid colors with important information. Ensure that the colors used do not express important information as illustrated in Figure 4.

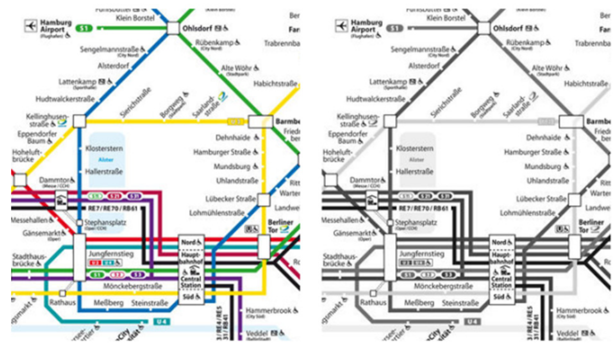

Figure 4: Rail system map of Hamburg with colored routes to distinguish. For people with CVD it is hard to differentiate.

Increase contrast between similar colors. Use additionally patterns, symbols and textures to create contrast between similar colors for people with CVD (see Figure 5).

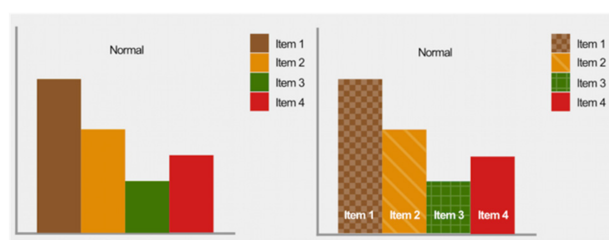

Figure 5: Contrasting patterns used in this chart and if possible placing text is useful [9].

Lighten light colors and darken the dark ones. This should help to distinguish that there are different colors (Figure 6).

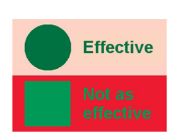

Figure 6: In contrast to the lower image part the upper part of the image the green color was darken and the red was lighten.

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Try to use a limited number of colors. Figure 7 shows a palette of seven colors. The colors in this palette are unique for people with normal vision and CVD. Some more palettes are available in [22].

Color	Color name	RGB (1–255)	CMYK (%)	P	D
	Black	0, 0, 0	0, 0, 0, 100		
	Orange	230, 159, 0	0, 50, 100, 0		
	Sky blue	86, 180, 233	80, 0, 0, 0		
	Bluish green	0, 158, 115	97, 0, 75, 0		
	Yellow	240, 228, 66	10, 5, 90, 0		
	Blue	0, 114, 178	100, 50, 0, 0		
	Vermillion	213, 94, 0	0, 80, 100, 0		
	Reddish purple	204, 121, 167	10, 70, 0, 0		

Figure 7: Conservative 7-color palette.

Avoiding well known bad color combinations. Green - Red, Green - Brown, Blue - Purple, Green - Blue, Light Green - Yellow, Blue - Grey, Green – Grey, Green – Black.

Label colors with text or symbols. We should apply symbols and text beside the colors to make the represented information clear (see Figure 8).

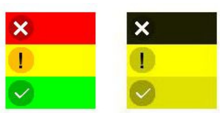

Figure 8: Added symbols to the colors to increase the impact of information. Right image is a CVD simulation.

Usage of Simulators

Due to the amount of existing tools, we refer to certain tools in [26-36]. Here, we focus on using some of these tools which we have used on a windows operating system.

Color Oracle [30] assures using the best available simulation algorithm. To simulate a preview of our applications we need to pick the CVD type from a popup menu (Figure 9). The illustrated preview is visible on the screen until we interrupt this by using any input device.

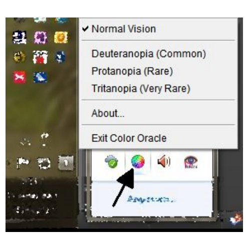

Figure 9: Color Oracle icon in windows taskbar.

The preview is a filtered screenshot of our main display. As a result of this, we create all possible CVD simulated images on our demo application (Figure 10).

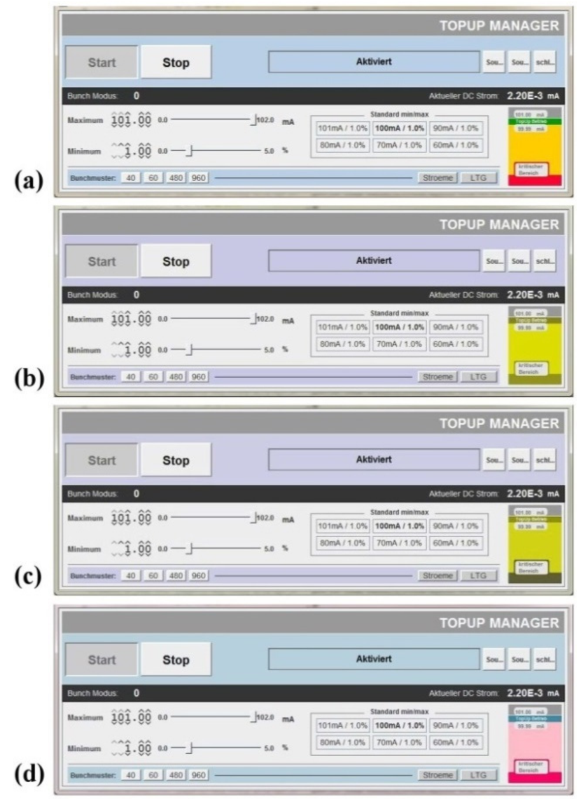

Figure 10: Application with CVD simulation (a) normal vision (b) deuteranopia (c) protanopia (d) tritanopia.

We investigated these images and checked if the colors and their arrangement to each other was a good choice. Only in in Fig. 10b the green and red color seems to be not distinguishable. So we made an improvement of the colors based on the mentioned CVD friendly design practices by reducing the saturation of the green color and the brightness of the red color (Figure 11).

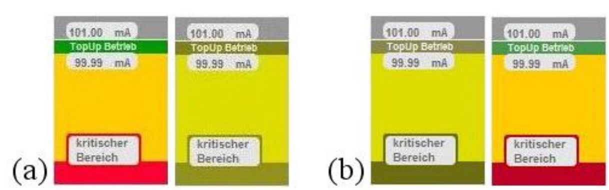

Figure 11: Deuteranopia view (a) first simulation, (b) improved color simulation.

The differentiation of colors has become more clearly. We also used text fields around the color fields to label the functionality. Unfortunately, color oracle does not simulate in real time. The developer needs to enable the intended simulation on screen every time manually.

Additional simulations tools like *Sim Daltonizer* [32] and *Colour Simulations* [33] are starting as a frame. Inside this frame, a selected CVD type can be simulated

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in real-time as demonstrated in Figure 12. Developers can get instantaneous feedback on how it would be seen by people with CVD.

Figure 12: Colour Simulations preview in real-time.

Another tool with valuable features is *Chromatic Vision Simulator*. Simulation is done by accessing a camera device in real time or by loading a picture. The simulated previews of the three CVD types can be seen simultaneously (Figure 13).

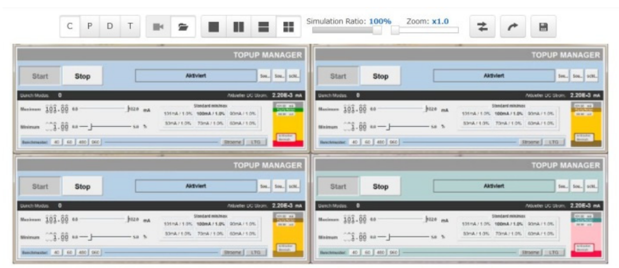

Figure 13: Chromatic Vision Simulator with parallel view of deuteranopia, protanopia and tritonopia

Discussion

Several software tools exist to visualize colors as they are perceived with different types of color blindness. These simulators are available as web applications, smartphone apps, rich client applications, libraries, and as plugins. These are useful to confirm if our design is accessible for people with color vision deficiency.

We used different features of these carefully chosen tools to investigate user interfaces during the development process. The availability of these tools depends on the operating system and many of them are open source projects. As a result integrating simulators into our user interface development, we prefer using a simulator with following main features:

- Simulator is executable within the used IDE as a part of the visual editor
- parallel simulation of different types of CVD
- Real-time preview to see effect of changes immediately
- Integrated color vision deficiency color palettes

For Control Room applications the choice of colors is not totally free. Traffic light colors are used for increasing the information density. A Component can be good (= green) or bad (= red) or warning (= yellow). Some more for no-information (= gray) or interface error (= orange).

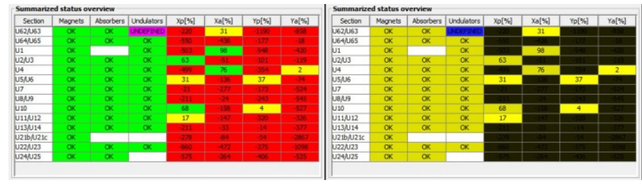

Figure 14: Control application with green, red, yellow colors used. The right image is a simulated view of faulty red cones.

Figure 14 shows a typical used control room application. As a person with red-green CVD it is difficult to distinguish green and yellow. To improve this view adding symbols may help. Additionally the black font with red background is not clearly readable. This is a cause of because of insufficient contrast. Another simulation of control room visualization component as charts is shown in Figure 15.

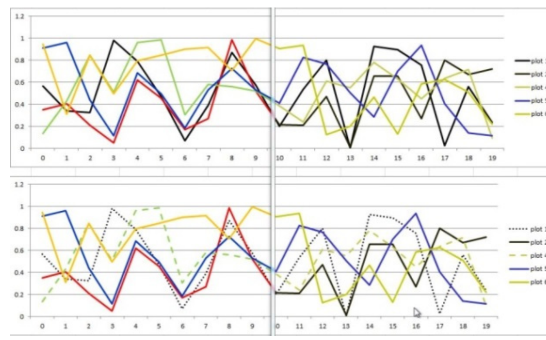

Figure 15: Charts are used to get history plots. Upper image is normal colored plot. The lower image is an improved plot by using line patterns. Simulated preview is presented on the right.

Future Projects

In our research we missed the support of visual editors to switch directly from the IDE to a simulated view. In future works we suggest providing plugins for the most popular IDEs in order to preview the CVD simulation in real-time. These plugins should implement the discussed features.

Another future work could be the improvement of available accessibility APIs in programming languages with CVD correction methods. Our intension is to enable features within applications, which can be used to individually adjust the application view for users with color vision deficiency.

CONCLUSION

Being aware of color blindness in user interface design was the main part of this work. During the development process we integrated color blindness simulation tools to validate if our design was suitable to people with CVD. Considering that people cannot distinguish colors helped us to get an enhanced sensitivity on selected and visualized colors.

We discovered that adjusted colors for accessibility do not lead to a loss of aesthetic integrity of a design.

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Appling the mentioned CVD friendly design practices and using simulators as assistance offer us the opportunity to be creative. In particular, traffic light colors (green, red, yellow) do not represent a problem at all for people with CVD.

Simulators helped us to get a good impression of how people with CVD actually see colors. Additionally, leading software systems come up more and more with guidelines for accessibility or helping tools for people with CVD to adjust the view on their device. [32-34, 37-47].

Nevertheless, it is important to keep in mind that no simulation will perfectly visualize what a color blind person perceives.

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