Digital Accessibility for Persons with Color-blindness

Monika Maria Möhring
THM - University of Applied Sciences
BliZ - Study Center for Blind and Disabled Students (THM)
Giessen, Germany
e-mail: mmm@bliz.thm.de

Felix Wegener
Vectorsoft AG
Heusenstamm, Germany

***Abstract*— The present work highlights the perceptibility of digital content for people with color blindness. It presents a pragmatic requirements catalog for user interface programmers and developers, devising layouts and digital prototypes that are to incorporate a mode for color blindness. Criteria catalogs, such as Web Content Accessibility Guidelines 2.1 are used for determining the requirements. A tool is employed to analyze the contrast of digital contents. Based on the results and the criteria of WCAG 2.1, an actionable catalog of requirements is presented. This work enables the determination of aspects of particular relevance. The paper thus provides information on color blindness and visual impairments, as well as a guideline that provides interested developers with "best practices" to optimize web applications in terms of accessibility and to utilize as a guide.**

Keywords - Web Content; Digital Accessibility by Design; Color-blindness.

I. INTRODUCTION

A person with an unimpaired color perception can perceive and process countless colors of the spectrum. However, it is estimated that around 0.4% of all women and 8% of all men are impaired in their color perception and do not perceive colors in the same way as 95% of all other people do. One form of color blindness is total color blindness, i.e., purely monochromatic vision, in which the affected person only perceives black and white, i.e., only the differences in brightness of the different colors. If, on the other hand, the perception of only one of the three primary colors red, green and blue is impaired, which occurs in around 60% of color-blind people, the term dichromatic vision is used. These can generally be divided into the following groups, which are also simulated and presented in Figure 1. A distinction can be made between protanopes and deuteranopes, red-green-blinds "whereby protanopes require high-intensity long-wave radiation for recognition, and tritanopes, yellow-blue-blinds" [1]. Protanopes and deuteranopes confuse colors, such as red, yellow, brown and green, cannot tell the difference between violet and blue, and protanopes in particular only see dark red as black. Color-blind people who belong to the tritanopic group, on the other hand, have difficulty distinguishing blue from green and yellow-green from grey. People who do not suffer from any impairment of their color perception, on the other hand, are referred to as trichromats, i.e., "people without color vision deficiency and with normal spectral sensitivity" ([1]: 270), although they may also have anomalies that make them perceive colors slightly differently than the majority.

Figure 1. Overview of a demonstration of vision with the different types of color vision deficiency the full colour spectrum [2].

This article describes various forms of dysfunctional vision concerning colors. It will set out why it is important for content creators to implement digital accessibility for persons with color-blindness into their design processes. It lays forth why this kind of digital accessibility is not only a technical issue.

This research also discusses technical tools available for content optimization.

II. AUXILIARY TOOLS USED

There are many different approaches for analyzing the contrast ratios of foreground and background. The developer tools of common Internet browsers can already be used to determine the contrast ratio by examining an element of the surface. However, this does not work for every element that you want to examine, so it makes sense to use other tools that can make the work a little easier and provide even more information. For the intended purpose, however, these tools must be able to do more than just display the contrast ratio. In addition to recommendations and cross-references to interesting articles, the authors of the WCAG 2.1 guidelines also provide recommendations for tools to determine contrast ratios [3]. One of the recommendations is the product of Utah State University's WebAim.org [4], which offers a web- based tool for free download that is designed to analyze the contrast ratios between two different colors (see Figure 2).

The tool makes it possible to analyze the content and use the data to make it more accessible for people with a possible visual impairment. In addition to using indicators to indicate whether the calculated contrast ratio is

compatible with WCAG requirements, the application offers users the option of simulating color blindness using a specific function and using a sample text to show how the respective contrast ratio is perceived by people with color vision impairments. The color values can be determined in several ways and can also be specified in the most common formats [2]. Users can also copy the results provided by the Color Contrast Checker and use them for other purposes. Even slight deviations of the text contrast from the maximum (black; see Figure 2) drastically reduce readability, as in the example of dark blue (see Figure 3).

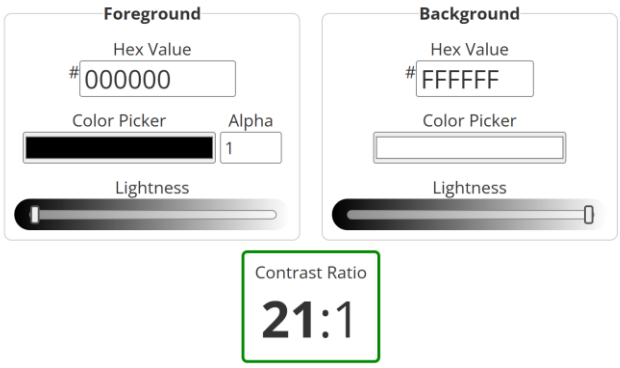

Figure 2. The user interface of the Color Contrast Checker [4] is shown here as an example.

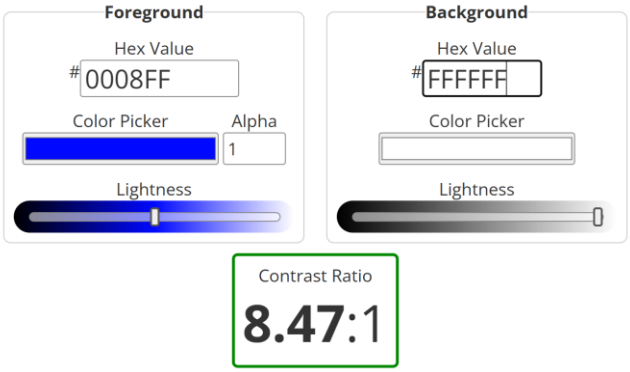

Figure 3. Reduction of contrast from 21:1 to 8,47:1 by replacing black writing with dark blue. Tool: Color Contrast Checker [4].

As demonstrated, this tool is used to examine and analyze the success criteria 1.4.3 "Contrast (Minimum)," 1.4. 6 "Contrast (Enhanced)," and 1.4.11 "Non-text Contrast“ of the WCAG [3] in more detail. The rest of the criteria can be carried out by examining the elements through the developer options of the browser employed.

III. CATALOG OF REQUIREMENTS

The basis is initially formed by the requirements from the WCAG guidelines [3], in particular from Guideline 1.4, which addresses the differentiability of content. The catalog designed is intended to sustainably improve the differentiability and perceptibility of texts, graphics, and user interfaces, thus optimizing those for users with color blindness/ color-related visual impairment. The requirements are also inspired by the related work of Ebert et al [5], whose analysis identified further requirements for web offerings.

A. *Color*

The most important feature of a color-blindness/ color-related visual impairment mode is the color factor. The success criterion for barrier-free use is that information is not conveyed exclusively via colors. This means that there are alternatives for conveying information, i.e., that color is not used exclusively as a transport medium. Options, such as the use of icons or the textual presentation of information are useful and should be considered. In addition, certain colors should be banned as a matter of principle or the use of colors, such as green, red or blue should be avoided within the digital content, as there are known color vision deficits [3], as in WCAG success criterion 1.4.1. In order to design, e.g., a successful prototype of an accessible web application, it is important to weigh up the benefits, aesthetics and purpose of the color scheme so that a meaningful overall design can be created. Text input via form fields in particular can become a challenge for those affected if an unsuccessful request is signaled exclusively via red color accents. This can lead to misunderstandings during operation, which users may perceive negatively and perhaps put them off completely. It is important not to make the different statuses of operating elements dependent on color and to consider alternatives. Labels that clearly and comprehensibly convey the required information and speak for themselves in their simplicity are suitable. An exclamation mark has roughly the same effect as the signal color red and can therefore convey just as strongly that certain inputs are necessary. It has however to be stated that some visually impaired users feel more comfortable when higher contrasts with colors are used instead of classic black and white ([3]: 85).

B. *Font*

In addition to the color of content, font size is also a decisive factor that significantly influences the legibility of content and, above all, text. This not only brings exclusive advantages for people with a visual impairment, but also makes content clearer and facilitates the identification of the functionality of the constituents of a website. As control elements are essential for the use of interactive platforms, it is important to design them clearly and legibly so that users can use the application as desired. The text size of elements should therefore not be less than 18.5px, as this can impair the quality of differentiability ([3], success criteria 1.4.3 & 1.4.6). If buttons or information-laden texts cannot be read, this unsettles users in their actions and can also have a deterrent effect. An overview and good legibility promote perceptibility and increase the differentiability of the content. Texts should be prepared in such a way that, if they are enlarged, they are still legible and the formatting does not suffer or deteriorate. All inscriptions should meet this

criterion, especially if users use supplementary assistive technologies. All of this contributes to the acceptability of a solution in that people with visual impairments can follow the text better and that it is generally clearer to read ([3], success criterion 1.4.4).

C. Contrast

In addition to the two previous factors, contrast is also of significant importance for differentiable content on user interfaces. For example, white text that meets all the criteria for legible text can hardly be perceived on a light gray background, simply because the contrast ratio is so low that the foreground can hardly be differentiated from the background. Poor contrast leaves control elements almost unusable and therefore also makes the platform unsuitable for efficient work. Particularly, in user interfaces that consist of countless control elements, it is essential that these are labeled and marked according to their function. If there is an insufficient contrast ratio between the foreground and background, the labeling can no longer be perceived and users can no longer understand what function the control element has ([3], success criteria 1.4.3 & 1.4.6 & 1.4.11). This implies that a good contrast ratio is essential for the interface and its controls. In the least, a standard value of 7.5:1 for normal text and labeling within images should be adhered to so that its content is optimally perceptible. Text with a large font size, on the other hand, only needs a contrast ratio of at least 4.5:1 to meet the requirements ([3], success criteria 1.4.3 & 1.4.6).

A current example is the logo of Merck KGaA in Figure 4.

Figure 4. Corporate logo of Merck KGaA [7]

Even though the font is large, the contrast ratio of 2,27:1 does not suffice for adequate readability. The reception of pictures can be simulated on Dalton Lens Website [8].

According to Brettel [9] et al., the result for red-blind readers (with so-called protanopia) would look like in Figure 5.

Figure 5. Simulation of Merck KGaA logo on Dalton Lens Website [8] using the Brettel method [9].

One of the additional findings of the analysis carried out at is that light/dark contrasts in particular improve the contrast ratio enormously. The use of a complementary contrast between red and green, on the other hand, is an absolutely avoidable scenario that should never find its way into a user interface.

D. Scalability

Another requirement to consider is the scalability of content. This means that the surface can be enlarged to up to at least 200% of the actual display size. On the one hand, this helps people with weaker eyesight to enlarge the content so that they can better perceive and differentiate it. On the other hand, this requirement makes it possible for users with devices that have a lower pixel density or smaller screens, for example, to enlarge the content. Above all, this ensures ergonomic advantages, as content is not only perceptible for all users, but can also be accessed regardless of the device. It is important that content retains its full functionality and is legible even with a larger zoom factor (see [3], success criteria 1.4.8 & 1.4.10). The results of the analysis of the collected data and the expert opinions [3] also confirm the assumption that it is desirable for users if user interfaces offer the possibility to adjust the size of texts without compromising the quality of navigation [3]: 85). The ideal case here is the use of a CSS flexible textbox system, as this offers automatic scaling by default and thus the elements adapt directly to the viewport [6].

E. Theming

In this catalog of requirements, theming means that users are given the opportunity to adapt the user interface to their own requirements. This means, for example, that colors or font sizes can be adjusted, giving users the chance to influence the interface. This ensures that users can adapt their user interface to their respective, but usually very specific, needs and thus have a certain amount of design freedom, which can make their own work more efficient. Some users can differentiate certain colors better than others and some texts are difficult to perceive even with a font size of 24px. The ability to edit circumvents this and users have a degree of control over their user experience ([3], success criteria 1.4.4 & 1.4.8).

IV. CHECKLIST

A checklist was drawn up to review the implementation of the requirements, which serves as a guide to good and bad practices and can be used as an aid. It is recommended that the aspects below be considered programmatically in order to be as barrier-free as possible.

Color

- Good:
  - o Icons or texts as an alternative to pure color
  - o Add tooltips to hover animation -> with concise information
- Bad:

o Use of red/green/blue tones
o Convey information only via colors

font

- Good:

o normal text at least 24px in size, bold text at least 18.5px in size
o Sufficient line, word and letter spacing
o Short and concise information texts -> aligned left or right

- Bad:

o Narrow and confusing text blocks
o text blocks too long

Contrast

- Good:

o at least a contrast ratio of 4.5:1 or higher for large texts
o a contrast ratio of 7.5:1 or higher for normal texts
o a contrast ratio of 7.5:1 or higher for the control element and its labeling

- Bad:

o Background and foreground with the same color but different saturation
o use the complementary contrast of red and green

Scalability

- Good:

o Working with the Flexbox system -> automatic scaling and adjustment
o Set up breakpoints
o Assign values in units, such as %.

- Bad:

o Make elements static or sticky
o Fixed pixel values for elements independent of the font size

Theming

- Good:

o Offer design freedom -> changing CSS values is possible

- Bad:

o Fixed and unchangeable themes

V. DISCUSSION AND CONCLUSIONS

Colorblindness is one of the less considered impairments leading to inaccessibility of digital contents and web interaction. In education, at the workplace, and in consumer marketing, there is a need for an increased awareness of contrast and recognizability issues.

High contrast is also increasingly a prerequisite for artificial cognition of text. In combination with, among others, screen readability, alt text, magnification functionalities, contrast ensures a comprehensive readability of text and understanding of graphics.

This contribution exemplified how contrast checking tools can be used for optimization of usability, reception, and understanding. It devises a best-practice checklist for both designers and information technologists.

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