Web Design for Color Blind Persons

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Abstract:

People with "normal" color vision don't see the full available spectrum of waves either. The visible light is only a relatively narrow section. Ultra-violet or infra-red "colors" are undetectable for humans. Unless of course we consider being able to get a tan from UV light or heat up from the warmth of infra-red as detection, color blindness very rarely means that we can't see any color at all, or that people see things in grayscale. It's actually a decreased ability to see color, or a decreased ability to tell colors apart from one another, color blindness is a sex-linked trait and it's much more common in men than in women. The most common type of color blindness is called deuteranomaly which occurs in 7% of males, but only 0.5% of females. Color blindness can be a real drawback for anyone in the design field since color theory is an integral feature in successful design, and a lot of decisions are based on the feeling and emotion derived from design decisions, rather than a generic set of guidelines and taxonomies, it's important to cater for the widest audience, who could potentially have problems with our website if not designed in the right way, but the main aim of this paper is actually looking at how non-sufferers web designers can still take into account the needs of their color blind audience, and we look for a clearly distinguishable of hues of five colors (black,red,green,blue and yellow) which are frequently used in these circumstances. Red-Green confusion people don't confuse all kinds of red and all kinds of green . By selecting particular hues for each color, the ability to distinguish between the five colors should be greatly improved.
The study thus conclude that, by carefully selecting hues within the range of each color category ,it's possible to establish color combinations which are easily distinguishable to people of all color vision types in order to facilitate visual communication.

Keywords:

Web Design, Color Blindness, Protanopia , Deuteranopia, Tritanopia, contrast checker, Color Wheel, Wave tool, Color Laboratory, Color Oracle.

Introduction :

Color Blindness is a mild disability in which distinguishing color can be an issue. There are multiple types of color blindness. Total color blindness ("monochromacy") is a very rare condition, in which people only see different tones and brightness levels, with no color at all. However, more common cases are an inability to recognize blue/yellow or red/green, with the latter being the more common of the two.
The research problem is the inability of people with color blindness to identify certain colors amongst similar others, or just none at all. The research aim to design a successful web site for good use of color and how non-sufferers web designers can still take into account the needs of their color blind audience.
Some previous studies have addressed the subject of color blindness, in 2003 Pearson Education Inc. presented a research on color blindness which depends on other studies of normal vision reading and color contrast on normal vision by Legge, Rubin and Luebker (1987).
Other research conducted by Lighthouse International (Arditi, 1999a, 1999b) and the American Printing House for the Blind (Willis, 1996; Henderson, 2001, 2002) was also used to shape the use of effective color contrast for Stanford 10.
In 2006, The Color Universal Design Organization (CUDO) and EIZO NANAO CORPORATION in Japan issued The Color Universal Design Handbook. Color Universal Design is a user-oriented design system, which has been developed in consideration of people with various types of color vision, to allow information to be accurately conveyed

to as many individuals as possible.

Yasuyo G. Ichihara the professor at the faculty of informatics, Kogakuin University, and member of Color Universal Design Organization (CUDO) presented several studies including a study in 2000, entitled suitable digital color palette for individual human color vision sensitivity . In 2001 he presented two studies entitled The difference between seeing random color dot picture and reading shapes from the same color dot picture in the Ichihara pseudoisochromatic plates, and what do you see in digital color dot picture such as the Ichihara pseudoisochromatic plates?.

Research Problem

The research problem is the inability of people with color blindness to identify certain colors amongst similar others, or just none at all.

Color blindness can be a real drawback for anyone in the design field since color theory is an integral feature in successful design, and a lot of decisions are based on the feeling and emotion derived from design decisions, rather than a generic set of guidelines and taxonomies, it's important to cater for the widest audience, who could potentially have problems with our website if not designed in the right way.

Objectives:

- Non-sufferers web designers must take into account the needs of their color blind audience who could potentially have problems with our website if not designed in the right way.
- Access to the right contrast ratios and compliant colors by choosing the right color code for a foreground, and a color code for a background, so that color blind persons with different types of color blindness can still distinguish colors.
- Helping color blind persons with different types of color blindness to get the information correctly and directly without confusing, by using a combination of color and helpful elements, not only relying on color coding alone.

Methodology:

The study is based on analytical descriptive researches in order to describe and analyze the web design for color blindness persons.

1. Color Blindness Types

1.1 Protanopia

Protanopia affects approximately 1 percent of the male population.

Protanopia is the absence of red sensitivity, also referred to as red dichromacy. It's the result of the loss of function of the L cones, which provide us with sensitivity to the red portion of the visible spectrum. With red being at the end of the visible spectrum, there is only a partial overlap of sensitivity with the two other types of cones, and so people with Protanopia have a distinct loss of sensitivity to light at the red end of the spectrum.

1.2 Deuteranopia

Deuteranopia affects approximately 1.1 percent of the male population.

Deuteranopia is the absence of green sensitivity, also referred to as green dichromacy. It is the result of the loss of function of the M-cones, which provide us with sensitivity to the green portion of the visible spectrum. Due to the location of green in the spectrum, to the actual sensitivity overlap between the M-cones (green) and L-cones (red), and to the partial overlap with the S-cones (blue), people with Deuteranopia have a fairly normal level of sensitivity throughout the spectrum, although they will still experience confusion among the individual colors.

1.3 Tritanopia

Tritanopia affects approximately 0.001 percent of the male population.

Figure 1: Color Blindness Types

Tritanopia is the absence of blue sensitivity, also referred to as blue dichromacy. This is the least common of all forms of color-vision deficiencies, and is the result of the loss of functionality of the S-Cones, which provide sensitivity to the blue portion of the visible spectrum. Because blue is at the opposite end of the spectrum from red, and because the sensitivity of the S-cones has less overlap with the other two cones, people with Tritanopia have a much more severe loss of sensitivity across the spectrum. see figure(1)

2. Designing a website for color blind persons

2.1 Designing as Monochromatic Colors

Monochromatic color schemes are not to be confused with monochromacy. Monochromacy is the color blindness which is very rare and makes the sufferer only see a single color, in multiple shades. Monochrome is, in fact, intended to be in such a way, with designs consisting entirely of a single color in multiple shades, versus using multiple colors.

Using a monochromatic color scheme is not necessarily a hindrance. In fact, it can be a great advantage to give unity within our design. for black , we could class it as a second color, but we can still achieve similar contrast with just using a very dark variant of our chosen color.

Achieving contrast is super simple when using a monochromatic color scheme. Since those with color blindness can still recognize different shades of color, introducing contrast is no problem since it is recognized in the same way.

Of course, a monochromatic color scheme can be used with any single color and can be quite effective in that way.

However, for those that instantly thought "black and white" when we mentioned monochrome, that's effective too. A lot of minimalist sites use a grayscale color scheme, which should be no problem for anyone to view in the intended way. If we want to stay safe, grayscale can look awesome, as long as it fits into the overall tone and feel of our design.

2.2 Bad Color combinations

2.2.1 Red/Black Combination

Some color blind users are lacking the capability to detect the lower color wave frequencies associated with red. For these users, red color waves read as "no signal", or "black". These users confuse red and black, so this contrast should be avoided whenever possible. Red and white is legible, but indistinguishable from black and white. In figure (2) we can note that the black text on red sign becomes black on black for some color blind users.

Figure 2: Red/Black Combination

2.2.2 Red/Green Combination

Almost 10% of men are red/green color blind; another group are blue/yellow color blind. Despite the fact that red-green contrasts are very distinct for about 95% of humanity, there are about 5% of people for whom this is non-functional. This is exacerbated by the fact that red and green are nearly identical on a gray scale monitor.See figure (3).

Figure 3: Normal Color Vision

2.2.2.1 Normal Color Vision

The paragraph above in figure (3) is "merry Christmas" in green text on a red background which a color blind person may not be able to read. This is also problematic because it causes a visual vibration for users with normal color vision.

2.2.2.2 In Gray Scale

In grayscale, there is only a slight contrast because red and green are of nearly equal brightness. see figure (4)

Figure 4: In Gray scale

2.2.2.3 In Deuterope Mode (Red/Green Color Blindness)

Appears as dark olive on medium olive in normal color vision. See figure (5)

Figure 5: In Deuterope Mode

2.2.2.4 In Tritanope Mode (Blue/Yellow Color Blindness)

Actually appears as teal and magenta. See figure (6)

Figure 6: In Tritanope Mode

2.3 Designing for High Contrast

High amounts of contrast is really important here because it's a great way of creating a consistent color scheme. We can create very light to very dark shades of a single color, giving us a wealth of different values to use. For example, if we were using a light blue for our background, we'd want to use a much darker blue for the text in order to keep our text legible. Using monochrome offers color blind visitors a way of easily appreciating our design, even if they can't necessarily identify the intended colors. However, high contrast offers a great deal of readability improvements to any user and is a designing principle we should be aware of away from accessibility.

2.4 Designing for Hue , Saturation & Brightness

Like tweaking contrast, modifying the hue, saturation and brightness of colors can help us show definition and allow users to distinguish, without using multiple colors. By sticking with a small set of colors, or even just one, changing the saturation can really show a distinguishing contrast within two samples of a color, as can brightness and hue.

These methods allow web designers to easily define different bits of their design through color, without having to worry too much about the aesthetics as if they were adding a new color to the mix. For the color-blind visitors, this allows for distinguishing different looking parts easily.

In figure (7) both examples started out as exact duplicates. However, the hue has been turned up slightly on the right.

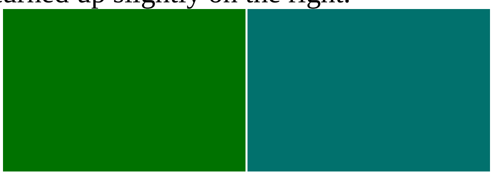

Figure 7: Hue

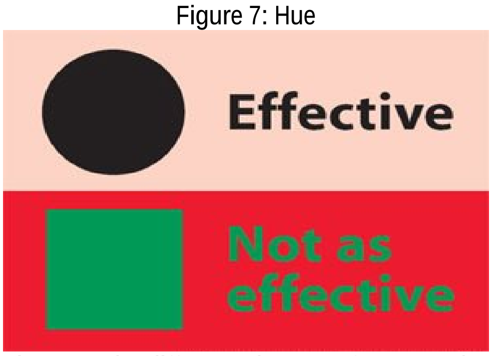

Figure 8: The difference between foreground & background color

2.5 Effective color choices

we need to exaggerate the difference between the foreground and the background and avoid using colors with similar lightness no matter how they differ in saturation or tone. see figure (8)

It is wrong to think that the lightness of the images we embrace will be the same for people with color deficit. So, if we lighten light colors and darken the dark ones, we will increase its visual accessibility.see figure (9)

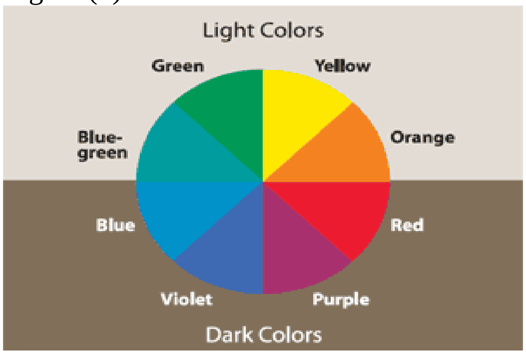

Figure 9: Color wheel

This diagram shows why it is preferable to choose dark colors with hues from the lower half and light colors from the upper half. It is essential to avoid making the contrast between light colors from the bottom half against dark colors from the top half. see figure (10)

The color blindness effect makes the colors on the bottom part not so effective comparing with the colors from the upper part. see figure (11)

we need to avoid using the contrasting hues from the adjoined parts of the circle if those colors do not contrast in lightness. See figure (12)

Figure 10: dark colors from lower Half and light colors from upper Half

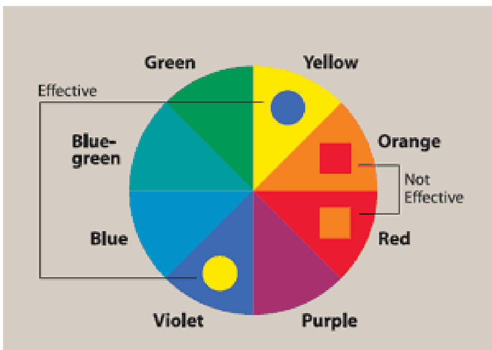

Figure 11: color wheel contrast

Figure 12: color contrast

Color blindness or partial inability to differentiate colors makes it harder to define the hues of a similar color. Making a suitable design for all forms of color blindness can be very difficult. If we keep in mind the following basic perceptions of color, we can create user interface that would fit people with color deficit. So hue, saturation, lightness can determine color perception. Hue is an attribute which is associated with the main color names. It allows us to define main color categories (blue, green, yellow, red and purple). The normal color vision allows to define hues one to another according to their similarity and on the contrary color blindness lessens the ability to follow the correspondence of those hues.

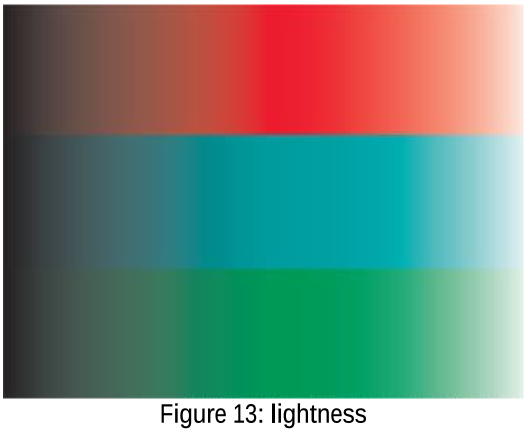
Figure 13: lightness

Lightness is an amount of light reflected from a specific object in correspondence with nearby objects. This color attribute is purely perceptual and makes the contrast more effective. Color blindness diminishes the ability to define color on the basis of lightness. see figure (13)

In Figure (14) color blindness makes the person see the left part of this image as the one with normal color vision sees the right part. Because of the color blindness people are not able to differentiate colors on the basis of these three attributes (hue, lightness and saturation). Web designers can diminish this deficit by increasing the difference between those attributes.

2.6 Borrowing Colors

This is mainly a tip aimed at designers who are color-blind, rather than those simply considering their color-blind audience. They can "borrow" colors from fellow web designs, or other non-web-based designs nowadays. By simply pulling out the eyedropper tool from our arsenal of graphic editing tools, we can easily identify colors within a design and start using them in ours. Borrowing color schemes can be a really effective way of identifying what works well and replicating it in a different form while maintaining the successful intentions of a successful scheme. Once we've identified colors and got them represented by hex values, we can use it in conjunction with other methods. It might be harder, but we should vary our palette and invent it ourselves, without lifting the entire scheme from another's design.

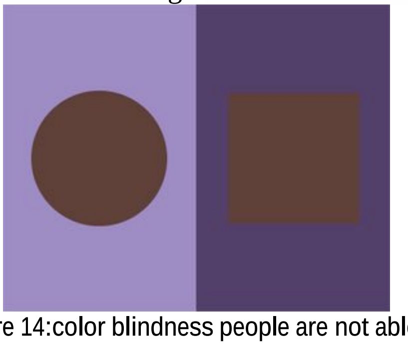
Figure 14:color blindness people are not able to differentiate colors

2.7 Including color names

People who are color-blind often have difficulty purchasing clothing and they will sometimes need to ask another person for a second opinion on what the color of the clothing might actually be. While it's easier to shop online than in physical store , there still accessibility issues to consider in shopping websites.

For example if there's a website that sells T-shirts, If it only shows a photo of the shirt, it may be impossible for a person to tell what color the shirt really is. For clarification, we should be sure to reference the name of the color in the description of the product. see figure (15). Another common problem occurs when a color filter has been added to a product search. Here's an example from a clothing website with unlabelled color swatches, and how that might look to someone with deuteranopia-type color blindness. see figure (16).

Figure 15: Adding Color Name

Figure 16: Color Filter

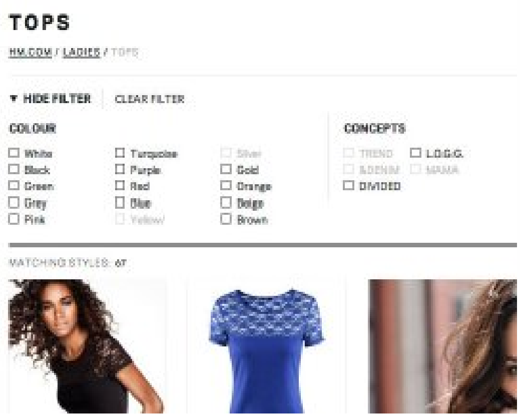

Figure 17: Adding Color Name

The color search filter in figure (17), is much better since it uses names instead. Using overly fancy color names, like the ones we might find labeling high-end interior paint can be just as confusing as not using a color name at all. Names like grape instead of purple don't really give the viewer any useful information about what the color actually is on a color wheel. Is grape supposed to be purple, or could it refer to red grapes or even green ؟We should stick with hue names as much as possible.

2.8 Avoiding color-specific instructions

When designing forms, We Should avoid labelling required fields only with colored text. It's safer to use a symbol cue like the asterisk which is colour-independent.see figure (18).

Figure 18: Form Design

A similar example would be directing a user to click a green button to purchase a product. We Should Label the buttons clearly and reference them in the site copy by function, not color, to avoid confusion.

2.9 Color Coding

Designing accessible maps and infographics can be much more challenging. We must not rely on colour coding alone , we have to try to use a combination of color and texture or pattern, along with precise labels, and reflect this in the key or legend. Combining a blue background with a crosshatched pattern, or a pink background with a stippled dot, the users will always have two pieces of information to work with. See figure (19)

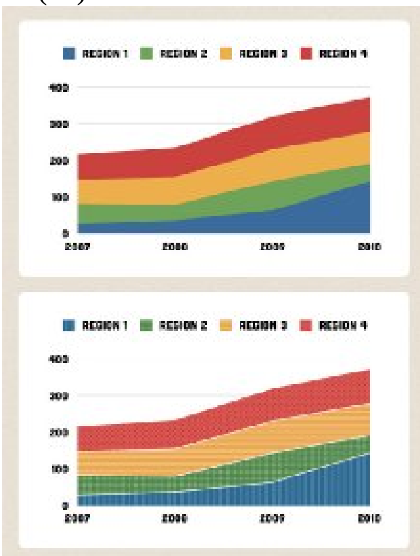

Figure 19 : combination of color and texture or pattern

3. Checking with a simulator

There are many tools out there for simulating different types of color blindness, and it's worth checking our design to catch any potential problems up front.

3.1 SimDaltonism Tool

It'll show a pop-up preview next to our cursor and we can choose which type of color blindness we want to test from a drop-down menu.

3.2 Photoshop & Illustrator Proof

We can proof for the two most common types of color blindness right in Photoshop or Illustrator (CS4 and later) while we're designing.

3.3 The Color Contrast Check Tool

The designer and developer Jonathan Snook gives us the option to enter a color code for a background, and a color code for text, and it'll tell us if the color contrast ratio meets the Web Content Accessibility Guidelines 2.0. we can use the built-in sliders to adjust our colors until they meet the compliant contrast ratios. This is a great tool to test our palette before going live.See figure (20).

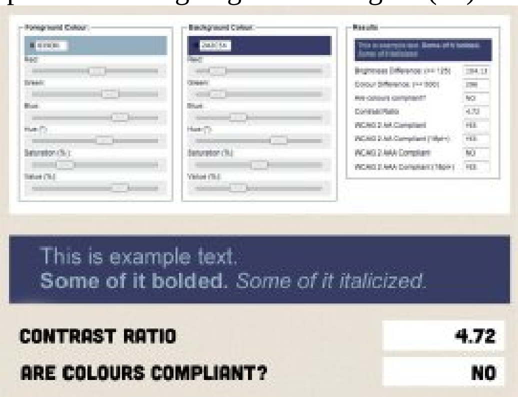

Figure 20 : The Color Contrast Check Tool

3.4 Wave Tool

For Live website, we can use the accessibility tool called wave which also has a contrast checker .

3.5 Color Laboratory Tool

It actually allows us to check out how colors look in conjunction with each other so we can easily create color schemes that work well for anyone - sufferer or not - on any operating system.

3.6 Simple Form Tool

It allows us to paste in our HTML and swap out hexadecimal color values with the color-blind equivalent, allowing us to easily tweak them in order to create a palette that is appealing to sufferers and non-sufferers alike.

3.7 Vischeck Tool

It allows us to preview a live webpage, or some images, in one of three types of color vision deficits. It even has a tool that will correct images so color-blind viewers can see them naturally.

3.8 Color Oracle

An application that will simulate the different types of color blindness on our computer. It can test our design at the Photoshop mock-up stage before we begin to code.

4. Results

Protanopia is the absence of red sensitivity, also referred to as red dichromacy. Deuteranopia is the absence of green sensitivity, also referred to as green dichromacy. Almost 10% of men are red/green color blind, they confuse red and green. So we used the color contrast check to reach the compliant colors and contrast ratio with which red-green confusion people can distinguish between the two colors.

In figure (21) we used a combination between green for the foreground colored text and red for the background color, we used the built-in sliders to adjust our colors, we moved the slider of the green color to the right end, then we moved the slider of the red color until we met the compliant contrast ratios and recorded the result as shown in table (1).

Figure 21 : Red/Green Combination (1) in Color Contrast Check Tool

Table 1 Red/Green Combination (1)

color	Green (Foreground)	Red (Background)
code	#00FF00	#F50000
Color Compliant	Sort of	
Contrast Ratio	3.13	

These results show that with green color for the foreground "code #00FF00" and red color for the background "code #F50000", the contrast ratio was 3.13, and there was a sort of color compliant with which Protanopia and Deuteranopia persons who confuse red-green combinations can still distinguish between the two colors to some extent.

Figure 22 : Red/Green Combination (2) in Color Contrast Check Tool

In figure (22) we repeated the test moving the slider of the red color to the right end, then we moved the slider of the green color until we met the compliant contrast ratios and recorded the result as shown in table (2).

Table 2 Red/Green Combination (2)

color	Green (Foreground)	Red (Background)
code	#00F500	#FF0000
Color Compliant	Sort of	
Contrast Ratio	2.68	

These results show that with green color for the foreground “code #00F500” and red color for the background “code #FF0000”, the contrast ratio was 2.68, and there was a sort of color compliant with which Protanopia and Deuteranopia persons who confuse red-green combinations can still distinguish between the two colors to some extent.

This means that red-green confusion people don’t confuse all kinds of red and all kinds of green. By selecting particular hues for each color , the ability to distinguish between the two colors should be greatly improved.

Tritanopia is the absence of blue sensitivity, also referred to as blue dichromacy.

In figure (23) we used a combination between blue for the foreground colored text and yellow for the background color, we used the built-in sliders to adjust our colors until we met the compliant contrast ratios and recorded the result as shown in table (3).

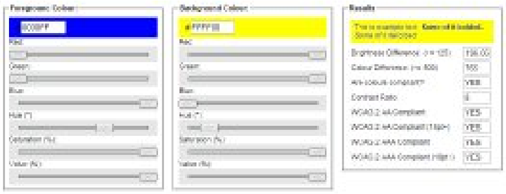

Figure 23 : Blue/Yellow Combinationin (1) Color Contrast Check Tool

Table 3 Blue/Yellow Combination (1)

color	Blue (Foreground)	Yellow (Background)
code	#0000FF	#FFFF00
Color Compliant	Yes	
Contrast Ratio	8	

These results show that with blue color for the foreground “code #0000FF” and yellow color for the background “code # FFFF00”, the contrast ratio was 8, and there was a good color compliant with which Tritanopia persons who confuse blue-yellow combinations can still distinguish between the two colors well.

This means that blue-yellow confusion people don’t confuse all kinds of blue and all kinds of yellow. By selecting particular hues for each color , the ability to distinguish between the two colors should be greatly improved.

In figure (24) we repeated the test but versa , we used a combination between yellow for the foreground colored text and blue for the background color, we used the built-in sliders to adjust our colors until we met the compliant contrast ratios and recorded the result as shown in table (4).

Figure 24 : Blue/Yellow Combination in (2) Color Contrast Check Tool

Table 4 Blue/Yellow Combination (2)

color	Yellow (Foreground)	Blue (Background)
code	#FFFF00	#0000FF
Color Compliant	Yes	
Contrast Ratio	8	

These results show that with yellow color for the foreground “code #FFFF00” and blue color for the background “code # 0000FF”, the contrast ratio was 8, and there was a good color compliant with which Tritanopia persons who confuse blue-yellow combinations can still distinguish between the two colors well.

This means that blue-yellow confusion people don’t confuse all kinds of blue and all kinds of yellow. By selecting particular hues for each color , the ability to distinguish between the two colors should be greatly improved.

Protanopia color blind users are lacking the capability to detect the lower color wave frequencies associated with red. For these users, red color waves read as "no signal", or "black". These users confuse red and black, in figure(25) we used a combination between red for the foreground colored text and black for the background color, but we selected a kind of vermillion to represent this red.

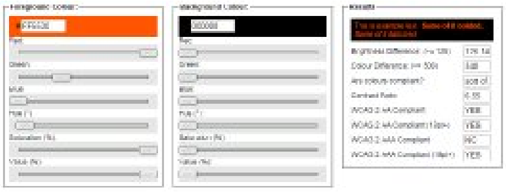

Figure 25 : Red/Black Combination in Color Contrast Check Tool

we used the built-in sliders to adjust our colors until we met the compliant contrast ratios and recorded the result as shown in table (5).

Table 5 Red/Black Combination

color	Red (Foreground)	Black (Background)
code	#FF5500	#000000
Color Complia-nt	Sort of	
Contrast Ratio	6.55	

These results show that with red color for the foreground “code # FF5500” and black color for the background “code #000000”, the contrast ratio was 6.55, and there was a sort of color compliant with which Protanopia persons who confuse red-black combinations can still distinguish between the two colors to some extent.

This means that red-black confusion people don’t confuse all kinds of red and all kinds of black. By selecting particular hues for each color , the ability to distinguish between the two colors should be greatly improved.

In figure (26) we used a combination between blue and Purple ,which are non compliant colors, so we used texture in addition to color to differentiate between objects, this helps color blind persons to read something like info graphic.

figure (27) shows a map containing some colors which are indistinguishable from each other to a person with a vision problem. This is true for any finding system that relies on color coding as the only key in a legend.

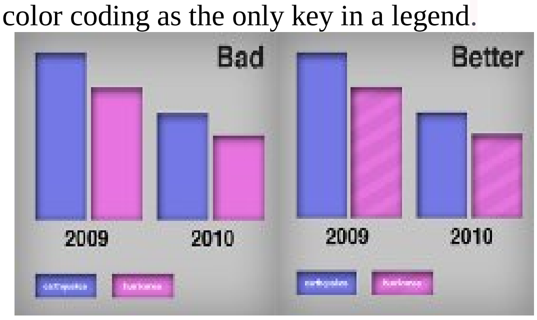

Figure 26 : Blue/Purple Combination before & after adding texture

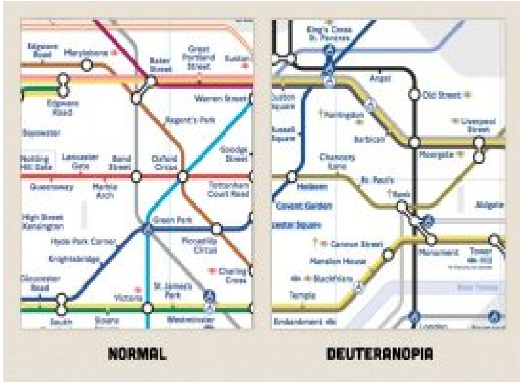

Figure 27 : Color Map

So we turned this colorful map to a black & white one , using patterns and shades of black and grey that are distinguishable.see figure (28)

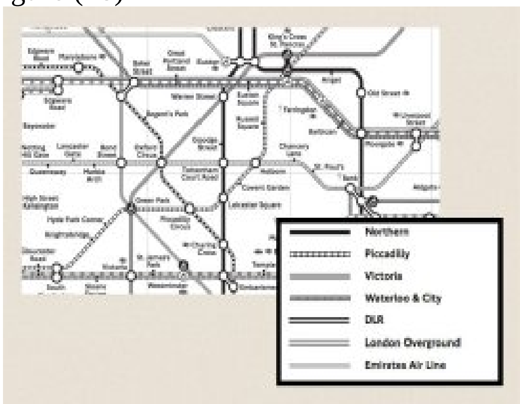

Figure 28 : Black and White Map with patterns and shades

5. Discussion

- Protanopia and Deuteranopia persons who confuse red-green combinations can still distinguish between the two colors to some extent. They don’t confuse all kinds of red and all kinds of green. By selecting particular hues for each color , the ability to distinguish between the two colors should be greatly improved.
- Tritanopia persons who confuse blue-yellow combinations can still distinguish between the two colors well. They don’t confuse all kinds of blue and all kinds of yellow. By selecting particular hues for each color , the ability to distinguish between the two colors should be greatly improved.
- Protanopia persons who confuse red-black combinations can still distinguish between the two colors to some extent. They don’t confuse all kinds of red and all kinds of black. By selecting particular hues for each color , the ability to distinguish between the two colors should be greatly

improved.

- Using textures with non compliant colors like blue-purple combinations , make a difference between the two colors, and helps color blind people to read something like info graphic.
- Turning a colorful map to a black & white one , using patterns and shades of black and grey make it distinguishable for color blind persons.

6. Conclusion

In this research, we looked for a clearly distinguishable combination of hues of 5 colors(black,red,green,blue and yellow) which are frequently used in different circumstances. Color combintion confusion people (red-green,red-black,blue-yellow) don't confuse all kinds of these color combinations.by selecting particular hues for each color , the ability to distinguish between the two colors should be greatly improved.Our study thus concluded that , by carefully selecting hues within the range of each color cateogry , it's possible to establish color combinations which are easily distinguishable to people of all color vision types in order to faciliate communication.

Selecting colors with specialist tools offer some insight into what color-blind visitors will see, and allow us to carefully select colors by making sure they look good for regular and suffering visitors. Checking our design with a simulator helps us to catch any potential problem up front.

Reliance on color alone is discouraged wherever possible. We shouldn't use only color to indicate something specific on our page. For example, a combination between blue and Purple ,which are non compliant colors, so using texture in addition to color to differentiate between objects, helps color blind persons to read something like info graphic.

For maps preferably to be black and white , using patterns and shades of black and grey that are distinguishable

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