By Colblindor

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Color Blind Essentials

Many people are looking for the basics about color blindness. So I wrote the following eBook on **COLOR BLIND ESSENTIALS** which should give you a good overview over the most central topics.

You will not only learn what color blindness really is, which forms of it exist and of course some details about the most well known red-green color blindness. But you will also have the possibility to read more about on how a color vision deficiency can affect your everyday life, if there is a way to cure or at least soften it and the different possibilities to test your color vision.

This eBook on **COLOR BLIND ESSENTIALS** includes the following six parts:

- **What is color blindness?**
- **Types of color blindness**
- **Red-green color blindness**
- **Color blindness tests**
- **Living with color blindness**
- **Curing color blindness**

If you want to learn even more about color blindness and closely related topics, you can either follow some of the links I provide in this eBook or visit my site at www.colblindor.com which includes a lot more information and even some tools and tests for color vision deficiency.

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1 What is Color Blindness?

Color blindness is not 'color blindness'! There are still a lot of people who think that if you are colorblind you really can't see any colors. But the term is misleading, as more than **99% of all colorblind people *can* see colors**. A better wording would be *color vision deficiency*, which describes this visual disorder more precisely.

1.1 So what actually is color vision deficiency also known as color blindness?

Simply put, *if you are suffering from a color vision deficiency you perceive a narrower color spectrum compared to somebody with normal color vision*.

This short definition raises a few more questions which need to be answered to understand the term color-blind more completely:

- **Why am I suffering from color blindness at all?**
- **What means *narrower color spectrum* compared to normal color vision?**
- **Are there different types of color vision deficiency?**
- **How do I know if I'm colorblind?**
- **Is there some possibility to cure color vision deficiency?**
- **Can I just live with it or do I have to be afraid of it?**

In the first chapter I will among other things answer the first two of those questions. The others will be looked at in the following chapters of this eBook about **COLOR BLIND ESSENTIALS**. But first of all I would like to take you back to the 18th century…

1.2 History of color vision deficiency

The first scientific paper about color blindness was written by John Dalton in 1793 entitled *"Extraordinary facts relating to the vision of colours"*. Dalton himself was red-green colorblind and as a scientist he took interest in this topic. He claimed that a **colored liquid inside the eyeball is the source for a different color perception**. This was proved wrong only after his death, when his eyes were examined and no such liquid was found.

After that Thomas Young and Hermann von Helmholtz were the first who described the trichromatic color vision. And once a theory for human color vision was ready, the basics of color vision deficiency weren't far away.

1.3 The cause of color blindness

Color perception in the human eye is build up by **three different types of cones**. Each type is sensitive to a certain wavelength of light (**red, green, and blue**) and every perceived color is therefore a mixture of stimuli of those three cone types.

Now, *if you one of those peaks of sensitivity is shifted towards another one or if one is missing at all, you perceive a narrower color spectrum—in other words you are colorblind.* As a peak can be shifted everything between a little bit and the whole way, **any type of severity is possible**. The closer the peaks are the more severe is your color vision deficiency: **slightly, moderately, strongly, or absolutely colorblind**.

"What do you mean by «narrower color spectrum»?"

Let's say somebody with normal color vision can identify and distinguish 150 hues. If you are colorblind this number starts to drop as you have fewer possibilities to create color mixtures from your color receptors. In case of absolute color blindness—missing one type of cone at all—you might be able to distinguish only as many as 20 different hues!

The type of affected cones also has a big impact on your color vision deficiency. As there are three different types of color receptors, there are also three different main forms: red (protan), green (deutan), and blue (tritan) disorders. As red and green deficiency result in quite comparable color vision problems, they are often taken together and known as **red-green color blindness**. You will find more information on the types of color blindness in the following two articles of this **COLOR BLIND ESSENTIALS** series.

Much less common possibilities for color blindness are also glaucoma, aging, alcohol misuse, or a hard injury on your head. Those factors often cause some milder form of blue-yellow color blindness (tritanomaly). Also other facts like signal transmission can cause problems in color perception, but this is not fully understood yet.

1.4 Why am I suffering from color blindness?

You know now the cause of color vision disorders, but we still have not evaluated why we can be colorblind at all.

We learned that in most cases color blindness is a **genetic disease** which is inherited from the parents to their children. This means, if one or both of your parents is suffering from some type of color vision deficiency, there is a certain chance that you or your children will have the same vision handicap. The chance is strongly related to the type of color blindness.

Before I get to show you a sample inheritance pattern, we will have a closer look at our chromosomes. Unfortunately it is not as simple as it could be, because there are different chromosomes involved in color vision. And on top of that even on the same chromosome several different genetic code pieces are participating.

The essence you should know is, that **red-green color blindness is a sex linked recessive trait** and **blue-yellow color blindness is an autosomal dominant trait**.

- *sex linked:* encoded on the sex chromosome X, whereas men only have one of them (XY) compared to women (XX).
- *autosomal:* encoded not on the sex chromosome, equal for men and women.
- *dominant:* if it is encoded on one chromosome, you have really suffer from it.
- *recessive:* if you have another healthy chromosome, it won't show up.

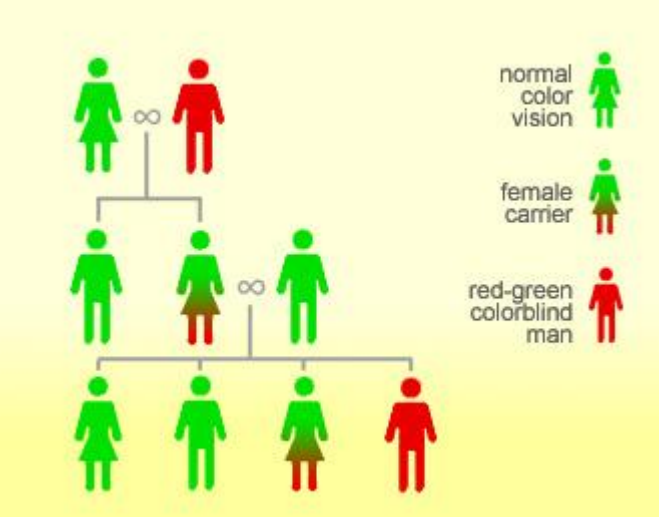
If you combine this together, we have **more colorblind men than women**. — *Why?*

1.5 Color blindness inheritance pattern

The above genetic encodings lead us directly to the inheritance pattern. This will also show us on a glance, why there are more men suffering from color blindness than women.

The diagram on the right shows the inheritance pattern of red-green color blindness. As you can see, this is a disorder which is **passed on from a grandfather to his grandson, whereas the mother is only a carrier** of it. A carrier is not affected because the trait is recessive. This causes much more men to be red-green colorblind, and even more women to be carriers of this color vision deficiency.

You can also learn from this diagram, that a woman can only be red-green colorblind if both of her parents are at least carrying the disease encoded in their genes.



Red-green color blindness inheritance pattern

1.6 Am I the only colorblind person?

No, definitely not. Color blindness is a very common disease which is found all over the world. Different scientific studies show, that roughly 8% of all men and 0.5% of all women are colorblind. This numbers are supported by different studies and are about the same all around the world. The high difference between men and women is resulting from the facts we just learned, that the most common form, **red-green color blindness, is a recessive sex-linked trait**.

Knowing this numbers you can also compute some very interesting probabilities in color vision deficiency:

- Approximately every 500st handshake is between two colorblind people.
- It is almost sure (probability: 94%) that at least one out of a football team is colorblind.
- If you pick out 100 persons, the chance is very low (< 1.5%) that none of them is colorblind.

2 Types of Color Blindness

In the first part of **COLOR BLIND ESSENTIALS** we learned some fundamentals about color vision deficiency like the history, occurrences, causes, genetic inheritance patterns and more. With this second chapter I want to explain you the **different types color blind people can suffer** from.

But before we learn more about them we have to have a look at how color vision actually works. We have to do so because the functionality of the eye is closely related to the three main types of color blindness.

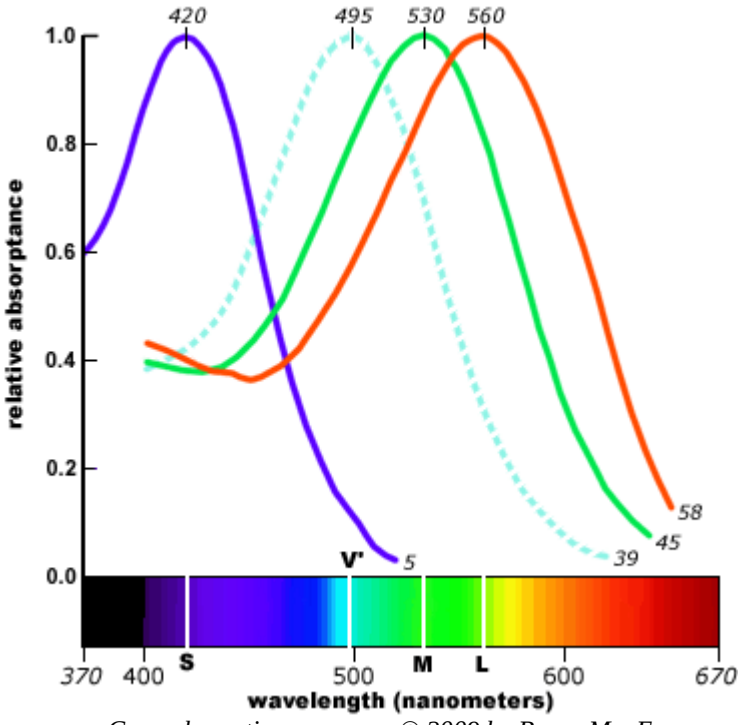
2.1 How color vision works

To see anything at all we need some tiny little helpers inside our eyeballs, the so called photorecptors. There are two different types of them: rods and cones. Both of them are sitting on the retina and pass information of light on to our brain. There are about **120 million rods which are very sensitive to light but not to color**.

The **cones are the photoreceptors which are responsible for our color vision**. They are only about 6 to 7 million of them but gathering together very closely in the center of the retina, the so called *fovea centralis*.

And here comes the clue: Each of those cones is carrying one out of three different photopigments and therefore reacts differently on colored light sources. For each of this three types exists a specific color absorption curve with peaks at different points in the color spectrum.

- **S-cones**: sensitive to short wavelength light with a peak at ca. 420nm (*blue*)
- **M-cones**: sensitive to medium wavelength light, peak at ca. 530nm (*green*)
- **L-cones**: sensitive to long wavelength light with a peak at ca. 560nm (*red*)



Cone absorption curves — © 2009 by Bruce MacEvoy

Mixing together the information of those three different types of cones makes up our color vision. This is also the reason that only three main colors are needed if we want to mix together all visible colors, because we have only three sources for mixing our whole color spectrum.

2.2 Types of color vision deficiency

Based on this knowledge about our visual system we easily can put together the list of different forms of color blindness. All of them have a direct relation to the available photoreceptors in your eye and are accordingly categorized.

- **Monochromatism:** Either no cones available or just one type of them.
- **Dichromatism:** Only two different cone types. Third one is missing completely.
- **Anomalous trichromatism:** All three types but with shifted peaks of sensitivity for one of them, which results in a smaller color spectrum.

Dichromats and anomalous trichromats exist again in three different types according to the missing cone or in the latter case of malfunctioning.

- **Tritanopia/Tritanomaly:** Missing/malfunctioning S-cone (blue).
- **Deuteranopia/Deuteranomaly:** Missing/malfunctioning M-cone (green).
- **Protanopia/Protanomaly:** Missing/malfunctioning L-cone (red).

For a better understanding you can also call them blue-, green-, or red-weakness respectively -blindness. Unfortunately this terms didn't really made their way and are not used very often.

Type	Denomination	Prevalence	
		Men	Women
Monochromacy	Achromatopsia	0.00003%	
Dichromacy	Protanopia	1.01%	0.02%
	Deuteranopia	1.27%	0.01%
	Tritanopia	0.0001%	
Anomalous Trichromacy	Protanomaly	1.08%	0.03%
	Deuteranomaly	4.63%	0.36%
	Tritanomaly	0.0002%	

Different forms of color vision deficiency

You could ask now: *"What about red-green color blindness or blue-yellow color vision deficiency? These are the ones I know and they don't show up in your lists here?"*

That's right. The problem with this well known terms is, that they are not telling the truth! Many people think that if you suffer from blue-yellow color blindness this are the only colors you can't distinguish. But that's wrong. **Color blindness doesn't relate to just two color hues you can't distinguish, it is the whole color spectrum which is affected.** More on this a little later in this article and in the next chapter of **COLOR BLIND ESSENTIALS** where we will have a closer look at red-green color blindness.

But to solve the puzzle: blue-yellow color blindness relates to tritan defects and red-green color blindness to all types of protan or deutan defects.

The above list includes also the prevalence rates of each type. These ratios of the most frequently occurring types for men are always the same: 1 protanope to 1 protanomalous trichromat to 1 deuteranope to 5 deteranomalous trichromat.

We already learned in the last chapter of **COLOR BLIND ESSENTIALS**: What is color blindness?, that because of the genes more men than women are colorblind. Adding up all the numbers results in a total of 8% of men and 0.5% of women who are suffering from some type of color vision deficiency.

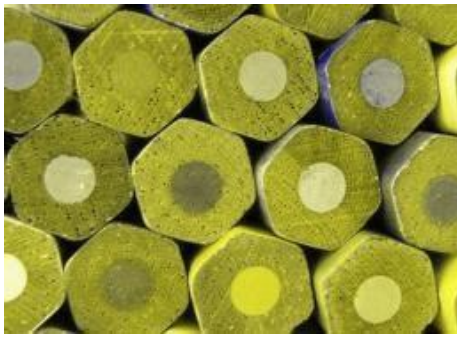
2.3 What do you see if you are colorblind?

We learned now a lot about the different types and categories of color vision deficiencies. But *what does it really look like if you are colorblind? How do you see the world if you are colorblind?* The four pictures below should give you a first impression.

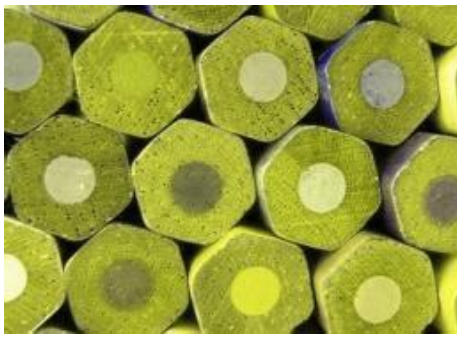
The pictures to the left were generated with a tool called Coblis, which you can find on www.colblindor.com

If you have normal color vision you might realize, that in the case of red-green color blindness (protanopia/deuteranopia) **not only red and green colors are affected but the whole color spectrum is perceived differently**.

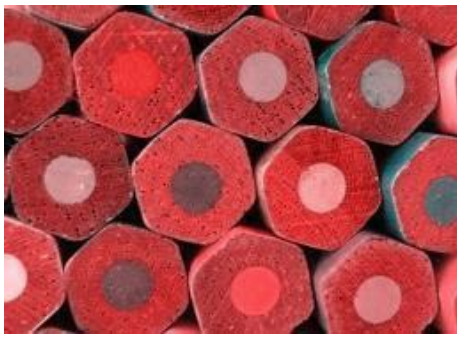
Normal Color Vision



Protanopia



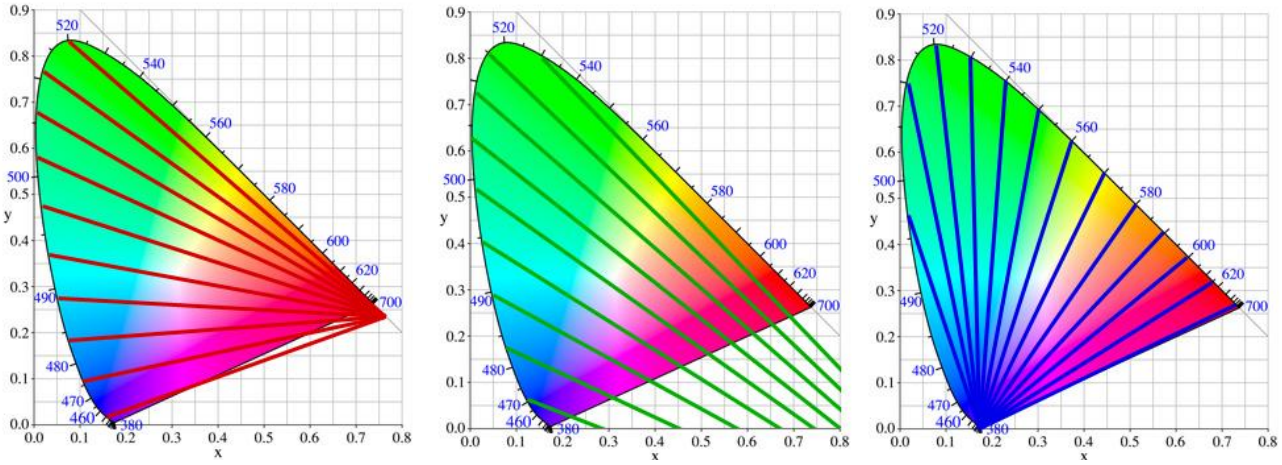
Deuteranopia



Tritanopia

The same of course is also true for blue-yellow color blindness (tritanopia). This is based on the fact, that all colors are perceived as a mixture of the three different cone types, and if one of them is missing the whole color spectrum changes.

The simulation below shows how the color spectrum changes. The shown lines are just meant as guides. Any line which ends in the so-called **copunctal point** connects the colors of confusion for a certain type of color vision deficiency. A more severe color blindness results in thicker and longer confusion bands in the color spectrum.



Protan, deutan and tritan lines of confusion in the CIE 1931 color space.

Simply put you can say, that **color blind people see the world as people with normal color vision see it at dusk or dawn**, when the colors start to fade away.

To learn more about how color vision works and to get a lot of interesting details about this topic, visit the excellent web site of Bruce MacEvoy on Color Vision.

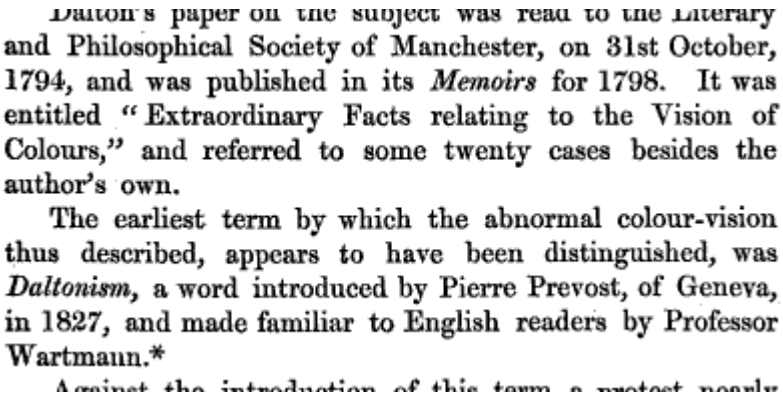
3 Red-Green Color Blindness

You could already learn a lot about the many different types of color blindness and what color blindness actually is. In this chapter of **COLOR BLIND ESSENTIALS** I would like to tell and show you some more and deeper details about the most common and also most well known of color vision deficiency: **red-green color blindness**.

3.1 Discovery of red-green color blindness

Already John Dalton wrote about his color vision deficiency, that red, orange, yellow, and green all appear to be the same color. The rest of the color spectrum seems to be blue, gradually changing to purple.

And Dalton concluded in the year 1798, that he can **not see long wavelength red light—known as protanopia** today.



Dalton's paper on the subject was read to the Literary and Philosophical Society of Manchester, on 31st October, 1794, and was published in its *Memoirs* for 1798. It was entitled "Extraordinary Facts relating to the Vision of Colours," and referred to some twenty cases besides the author's own.

The earliest term by which the abnormal colour-vision thus described, appears to have been distinguished, was *Daltonism*, a word introduced by Pierre Prevost, of Geneva, in 1827, and made familiar to English readers by Professor Wartmann.*

Against the introduction of this term a protest nearly

Memoirs of the life and scientific researches of John Dalton

Some recent genetic analysis of Dalton's preserved eyes showed, that he was suffering from deuteranopia—another form of red-green color blindness. But anyway this is the first description of the red-green color vision deficiency.

In 1837 August Seebeck carried out some systematic color vision tests and found **two different classes of red-green color blindness with differences in severity from weak to strong** in both classes.

After that investigations started to gather more details and scientists also learned more about our color vision. All this concludes in the knowledge we have today about the genetic source of color vision and its deficiencies and the precise knowledge about the mechanism of color vision in our eyes.

3.2 The facts

With the knowledge of the last two chapters on what color blindness really is and the different types of color blindness, we can put together the following list of facts about red-green color blindness:

Red-green color blindness is a **generic term** for protanopia (red-blindness), protanomaly (red-weakness), deuteranopia (green-blindness), and deuteranomaly (green-weakness).
More than 99% of all color blind people are suffering from a red-green color vision deficiency.
About **8% of all men** and **0.5% of all women** are suffering from it.
Any severity starting from slightly over moderately, strongly or absolutely is possible.
Red-green color blindness is a **recessive, sex linked trait** (encoded on the X chromosome). This results in much more men to suffer from it than women.
It is usually inherited from a **grandfather to his grandson** with the mother in between acting as the carrier of the disease.
Not only red and green can't be distinguished, but the **whole color spectrum is affected** by color vision deficiency.

Facts on red-green color blindness .

Unfortunately many people don't even know one of those seven basic facts on red-green color blindness. This often causes a lot of confusion and misunderstandings of this term.

3.3 Often confused colors

The following little story happened to me a few years back. I am suffering from a strong red-blindness, so this is really a true story:

I was standing on a balcony with a few friends on the fourth floor, looking into the grass fields down below us. After a while one of my friends asked, why the fire hydrant is standing in the middle of the field with no path close to it.

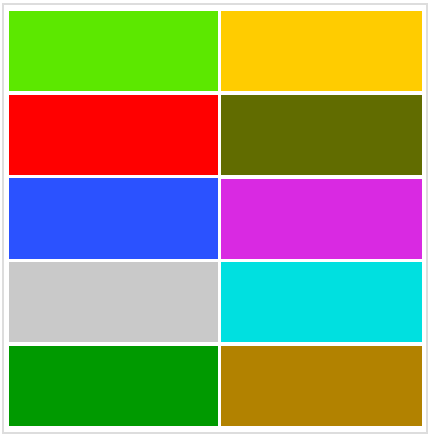
I looked down and asked: "Which fire hydrant?" — Silence — Laughter.

"Can't you see that orange fire hydrant in the middle of the field? It stands out so obviously with its orange color!"

I couldn't see it. Only after a while, scanning the field for a fire hydrant, I found it. But not because of its color but the structure of it.

This story is very typical as orange and green are some of the big problem colors for red-green color blind people. But not only those colors are mixed up. Colors from the whole color spectrum can cause problems in terms of not being able to distinguish them if you are color blind.

The table to the right shows five example color pairs of confusion. As severity and type of color blindness can be very different, such color pairs are quite individual. I have chosen some colors in the color spectrum which I—as a strongly red-blind guy—cannot distinguish.



Colors of confusion

As you can see, **not only the base colors red and green cause problems**. It is the mixture of the red part in the colors which makes colors indistinguishable for my eyes.

Remark: Moving in front of the computer screen or flipping the display fore- and backward can change the color perception a lot. Also if you print them out, colors are perceived quite differently specially from colorblind people.

On the other side not all reds and greens are indistinguishable colors for a red-green color blind person. Some greens and some reds can be seen and named even with a strong color vision deficiency.

3.4 Difference between red- and green-blindness

You know by now that red-green color blindness is actually just a generic term for any form of protan (red-blind) and deutan (green-blind) color vision deficiency. *But what is the difference between those two or why are they often put together into the same pot?*

Let us first have a look at the things those two different main types of color blindness have in common:

- The main axis of colors of confusion is the same and so both types have the same **main problem colors: red, orange, yellow, green, brown**.
- The **genetic information is located at almost the same place on the X chromosome**. Trichromatic vision developed much later in evolution while splitting the previous information of a single channel on red-yellow-green into those two different cone encodings.
- The **peak of sensitivity for red and green cone types is very close to each other**. Trichromatic anomalies result in the shift of one of those peaks towards the other one.

On the other hand there are also some differences which makes it possible to split red- and green-blind people into two separate groups while testing for color blindness:

- **Red-blind people perceive the color red much darker**. If you compare the results of Rayleigh matches—a color blindness test where you have to match yellow with a mixture of green and red—red-blind people use a much darker yellow to get a match.

- The **colors of confusion in the blue-purple area of the color spectrum are quite different**. Red-blind people will mix in much more red and still can get a match between blue and purple.

But if you compare those two types with blue-yellow color blindness the difference in between them are very small. Therefore you will most often just talk either about red-green or blue-yellow color vision deficiency and forget about the rest.

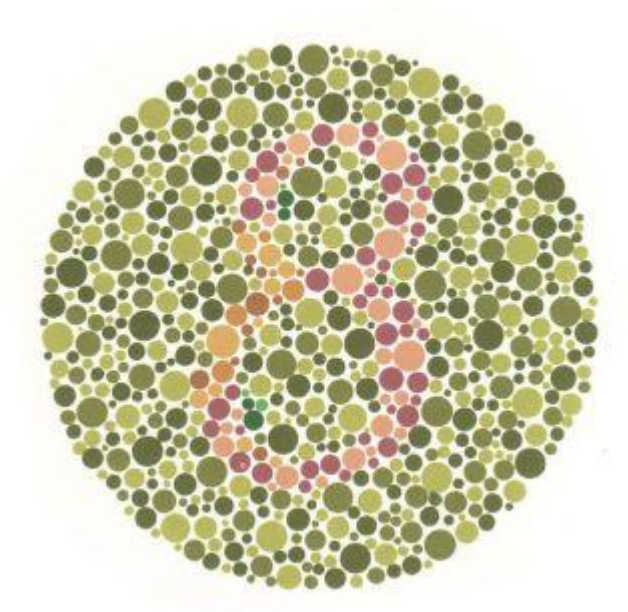
By the way, if you think about the terminology itself and including all the facts gathered together by now, you should know that red-green color blindness actually doesn't really exist *at all ;-).*

4 Color Blindness Tests

Most people relate the term *color blindness test* to the *dotted* pictures or even to the name *Ishihara*.

But this is not the only one, not the best one, definitely not the most current one, and most often an unsuitable test which is still used all around the world.

This part of the **COLOR BLIND ESSENTIALS** eBook focuses on **the different possibilities to test color vision**, how they work, what they can be used for and lists some of the well-known and used tests. There will be no conclusive enumeration as there are just too many tests around, with a lot of them not available anymore but still in use.



Ishihara plate

4.1 The first color blindness tests

Already in the 17th century Turberville found differences in some individuals **color naming, which was definitely one of the first color blindness tests**. About one hundred years later John Dalton described in detail his color vision and also tested other people with some colored ribbons which had to be named as well. At this time most often color vision deficiency was reported simply by subjective descriptions.

In 1837 August Seebeck used some more advanced technique. He used a set of more than 300 colored papers and let people **match or find a closely related color to a sample color**. This type of color vision test abandoned the naming of colors, which differs a lot between test persons.

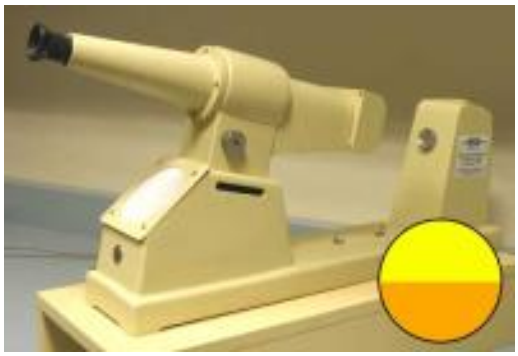
Through Seebeck's color blindness test two different types of red-green color blindness and a broad severity scale were discovered. Holmgren adopted this kind of test in 1877 by using skeins of wool. The **Holmgren wool test** was widely used and even commercially available more than one hundred years later.

The following two developments happened around the same time. They led to modern color vision deficiency testing.

- John William Strutt Rayleigh developed a precise color matching test. This match—still known as **Rayleigh match**—is not only the base of modern *anomaloscopes* but also made him discover **dichromatism and anomalous trichromatism**.
- Dr. J. Spilling published the first painted set of *pseudoisochromatic plates*. They were the predecessors of the famous **Ishihara plates**, which were produced the first time in 1917.

4.2 Different test forms

4.2.1 Anomaloscope



Anomaloscope

The anomaloscope provides the **most accurate possibility to test the severity of color blindness and distinguish between dichromats and anomalous trichromats**.

It is based on the *Rayleigh match*: A mixture of red and green light sources has to be matched with a yellow light source. Through the matching range it is possible to discover all different types of red-green color vision deficiency. Some of the anomaloscopes also include the *Moreland match* (blue-green) to test for tritan defects.

If you are a dichromat you will be able to make a match for all red-green mixture ratios. Anomalous trichromats don't accept the normal match and the distance of their match indicates the severity of their deficiency. On the other side, if you suffer a protan vision deficiency you will use much more red to match the colors compared to people with a deutan defect, which use more green in their mixture.

In 1907 the **Nagel anomaloscope** was introduced and is still known as one of the best. Unfortunately it is not produced anymore. Other well known instruments are the Neitz anomaloscope, the HMC (Heidelberg Multi Color) anomaloscope or the Pickford-Nicolson anomaloscope.

4.2.2 Pseudoisochromatic plates

Pseudoisochromatic plates are the most famous type of color blindness test. Most people know them under the name **Ishihara plates test**, because Dr. Shinobu Ishihara was one of the first persons who designed a very reliable plate test, introduced in 1917. He produced many different test sets and Ishihara plates are widely used all around the world.

The copunctual points build the source for this type of color vision test. The fact that colorblind people can't distinguish colors along the confusion lines is used to build a pattern of differently colored dots. If you are color blind you won't spot the dots which are shifted along the confusion lines and therefore numbers, letters, lines or anything else can be hidden from you.

There exist four different types of plates:

- *Vanishing design:* Only people with good color vision can see the sign. If you are colorblind you won't see anything.
- *Transformation design:* Color blind people will see a different sign than people with no color vision handicap.
- *Hidden digit design:* Only colorblind people are able to spot the sign. If you have perfect color vision, you won't be able to see it.
- *Classification design:* This is used to differentiate between red- and green-blind persons. The vanishing design is used on either side of the plate, one side for deutan defects and the other for protans.

Why can colorblind people see something which is not visible for people with perfect color vision? If you are colorblind you are not distracted by hue differences along the confusion lines. You will be more focused on lightness differences. These two different facts are used to design the hidden or invisible plates.

Besides the most famous Ishihara plates in a standard version of 38 plates, there exists a shorter version of 24 plates and a concise test containing 14 plates. **Ishihara plates can only be used to classify red-green color vision deficiencies.** Tritan defects cannot be tested by these tests.

The other well known pseudoisochromatic test plates are the **24 HRR plates by Hardy, Rand and Ritter**. This test was first produced in 1954 and can be used to classify all three different forms of color vision deficiency. There also exist a lot more of such tests but none of them is widely used. Even some electronic vision test equipments include certain pseudoisochromatic plates as a quick color vision test. But none of them is very accurate to get a concise test result.

4.2.3 Arrangement tests

Arrangement tests are also based on the theory of copunctual points. In contrast to the static pseudoisochromatic plates where you have to spot a path or number, an arrangement test is dynamic.

D-15 color arrangement test

Every such test consists of a **certain number of colored discs or plates which have to be arranged in**

the correct order starting from a pilot plate. The colors are chosen around the white point and because colorblind people can not distinguish colors along certain lines *through* the white point, colorblind people will arrange the discs completely different compared to somebody with normal color vision.

The most well known test was introduced by Fransworth in the forties of the last century and called **Farnsworth D-15 arrangement test**. As the names suggests this test includes 15 colored plates which have to be arranged in the correct order. You can try an online version of this test at Colblindor: Color Arrangement Test.

Some other well known tests in this category are the **Lanthony desaturated D-15 test**, which is used in case of milder forms of color blindness and the **Farnsworth-Munsell 100 hue test**. This test includes 100 different plates which have to be arranged in batches of 20 plates. Unfortunately the results are not that much better compared to the 15 plates versions.

4.2.4 Lanterns

The last well known type of tests was introduced by railway companies which found out, that some of their employees couldn't distinguish certain signal lights. **Lantern tests are specially designed to simulate signals** and are therefore most often used as vocational tests.

Compared to the other tests with lanterns you are testing the required ability directly, are robust and have a high practical value. On the other side you can't reveal much of the nature and severity of the color vision defect.

- **Holmes-Wright lanterns**: This lantern includes two different green, two red and a white light. Lights are shown in pairs of two, low or high brightness, either vertically or horizontally aligned. The test person is asked to name the colors.
- **Farnsworth lantern (Falant)**: This is the standard test in the US. It is comparable to the Holmes-Wright lantern but is specially designed to pass people with a mild form of color vision deficiency.
- **Beyne lantern**: France.
- **Giles-Archer lanterns**: UK.
- **Edridge-Green lantern**: UK.

4.3 Comparison of color blindness tests

The following table shows an overview of the different main test types for color blindness and compares them in certain dimensions. Every test type is graded from (-) not capable to (+++) excellent capability.

	Anomaloscope	Plates	Arrangement	Lanterns
Identifying CVD	+++	+++	-	+
Classifying type	+++	++	++	-
Grading severity	+++	+	++	+
Classifying dichromat anomalous trichromat	+++	-	-	-
Occupational suitability	-	-	+++	+++

Comparison of different color vision deficiency test types

Unfortunately Ishihara plates are used way too often to check for occupational suitability. Lanterns or certain arrangement tests would fit much better in this case. And if you like to have a precise diagnosis of your color vision deficiency there is no way around an anomaloscope.

4.4 The future of color vision testing

Today in our digital world one might think, *why don't we have some simple computer based color blindness test*. Unfortunately this is not as simple as it looks like. There are two main problems:

1. Computers displays just make use of three main colors red, green and blue (RGB). Every other color gets mixed from those three colors. The anomaloscope and lantern tests use different light sources which can't be simulated by a display.
2. Every computer display has a different color range it covers, little differences in light sources, different brightness and more. This causes different test results. Only calibrated computers can be used to perform such computer based tests.

The City University in London developed a computer based color vision test which is also based on the same principal as pseudoisochromatic plates and arrangement tests. The main difference is that the colors are constantly changing which gives some really good results. Just recently they used their test to check color vision in pilot candidates and it looks like as this could become a standard screening instrument for color vision testing for certain professions, where color vision is critical but people with a mild form of color vision still perform perfectly.

There is also some genetic testing available. But even such a *simple* impairment as color blindness is not easy to detect in the genes. So every genetic test always needs some physical tests in parallel to get a proper and concise test result.

Color naming would be a very simple test to identify color blindness, but for most cases it is too simple, too unspecific and not reliable enough. Therefore color naming can be used to simply check if you have a moderate to strong color vision deficiency but not for a detailed classification of your color vision deficiency.

5 Living with Color Blindness

"Which color is that?" is an often heard question if you are colorblind. You get used to it. You also learn how to handle it like most other difficulties which arise from your color vision deficiency.

I this chapter of the **COLOR BLIND ESSENTIALS** I would like to have a closer look at the everyday life of a colorblind person and also at the impacts this vision handicap can have on your career choice.

5.1 Color blindness in everyday life

Most people think that traffic lights are one of the biggest issues for everyone suffering from color vision deficiency, but they are wrong. The colors for traffic lights are very well chosen and they are always arranged in a certain order. So this is not a problem at all for most colorblind fellows even if some states don't allow you to get a driver's license if you are colorblind.

Original and its color blind simulation.

But there are some real handicaps for people who are suffering from some moderate to strong color vision deficiency:

- A **Sunburn** can't really be seen, only if the skin is almost glowing.
- If **meat is cooked** can't be told by its color.
- There is no difference between the colors for **vacant (green) and occupied (red)**.
- **Flowers and fruits** can't be that easily spotted sometimes.
- And you can't tell if a **fruit or vegetable is ripe** or not yet.
- Every electrical device which uses **LED lights** to indicate something is a permanent source of annoyance.
- **Colored maps and graphics** can sometimes be very hard to decipher.

By far the biggest issue is matching colors and specially matching clothes.

If you a have a color vision defect you can't just choose flowers which fit together nicely, or a painting which fits with the furniture, or a carpet. You also can't create a web site or an image with nicely matching colors. And you will never be able to easily match your shirt with your tie, your trousers with your shoes, your whole wardrobe. In this case you need a pair of *color enabled* eyes which help you out. I often borrow me the eyes of my wife and sometimes those of my son. They really help me a lot.

5.2 Choosing your career as a colorblind

A color vision deficiency often gets more attention when it comes to choosing a future career. Especially parents are very concerned about possible restrictions. But also young people ask themselves, if the job of their dreams will stay just a dream because of their vision handicap.

Jobs which require good color vision can be split into two different categories. In the first of them **color matching or color recognition is a main component of the job**. This for example includes color quality control, art teaching, interior decorating and more.

Professions that require good to perfect color vision
Airline pilot
Air traffic controller
Firefighter
Police officer
Train driver
Some ranks in the armed forces
Some electrical/electronic engineers

This group of jobs is easy to decide about for colorblind people as each one knows best himself if he will perform well in such a profession or not. Most colorblind people can also accept this fact more or less easily.

The other category includes jobs which also **require good color vision but only in support of the job itself**. This group includes the job profiles of pilots, firefighters, police officers and more. These kinds of jobs have to following facts in common:

- *Bad color vision is a security problem in this job.*
- *Passing a color blindness test is required to qualify for the job.*
- *The impact of a color vision deficiency is not well described.*
- *There is no international standard on color vision requirements.*

The points listed above unfortunately make it very complicated. Many colorblind people believe that they still could perform in such a position perfectly and that turning them down just because of their color vision deficiency is not correct. Some people even start thinking about how to cheat on such a test just to get through the exams and get the job of their dreams. But this is not the right way to go.

Here is my **six steps plan towards your future career**:

(1) Learn. During your time at school learn how you can handle colors. Learn about the severity of your color blindness and learn your special techniques to get around your handicap. This way you are very well prepared when it comes to choosing your future career.

(2) Inform. Get all possible information about the job of your dreams and possible handicaps for color blind people. You can get information from a prospective employer, from special authorities like the FAA for pilot candidates and of course from the internet. It's important to check your local requirements as they can vary between different countries.

(3) Talk. Try to find some people who are working in this job and talk to them. They will know the best if there are special tasks which might be a problem and you will know from your personal experiences, if you will be able to handle and also most important if you will feel comfortable in such a position. First check your relatives, ask around in your neighborhood, maybe you will find somebody at the college and otherwise I'm sure you will be able to find somebody online who will be happy to help you out. Just check forums where those people could hang around.

(4) Communicate. Don not try to hide your color vision deficiency. Be honest and communicate it if it might be a problem. Of course you only have to do this if color vision could be a possible handicap. But it is important to inform your prospective employer what you learned about the job to be done and how you overcome those handicaps despite your imperfect color vision.

(5) Go for it. Don't forget to take the last step. Do the required tests to learn more about your color blindness. You might pass without any problem and you might fail. You maybe also like to try different employers as there are in most jobs no national rules concerning color vision deficiency.

(6) Discuss. Did you fail the color blindness test and did they use the Ishihara plates or some similar form? Check my chapter about color blindness tests to learn about other possible tests. This should help you to start a discussion about the used test and if maybe this test was just too restrictive. There are many different tests available and sometimes it would be even much better if your prospective employer would just check possible job restrictions and if you can handle those or not.

And please don't forget the fact, many people have some form of handicap which is a burden and sometimes becomes a big obstacle. Get used to your color blindness and try to accept that moderate to strong color blind people shouldn't dream to work for example as a pilot or a professional firefighter. If you can't accept this, **don't try to cheat on the tests but start a discussion about it!**

Left: normal red apples — Right: colorblind red apples

We are colorblind. We can't name colors. But we can handle most situations perfectly even if we don't know which color it is.

6 Curing Color Blindness

If you first learn about your or one of your kids color vision deficiency there is one thing which comes to your mind often just after you learned what it really means to you: *Is there a cure for color blindness?*

The short answer to this question is simply: ***No***.
And the long answer: ***There is no cure for color blindness—yet.***

There are some scientific studies going on which had just recently quite a big breakthrough. This and some other interesting ideas about aids for colorblind people are the topic of the last chapter of my **COLOR BLIND ESSENTIALS** eBook.

6.1 First ideas

As with many other handicaps or diseases when some people learned that some others can't really distinguish colors like themselves, *laziness* was the first thing which came to their mind. Because of that many colorblind people just started to learn color names more intensively—without any success.

> *"No method had been found for the correction of color blindness [and] any treatment which convinces operators that they can see colors they could not see before will decrease safety in transportation, decrease security in national defense, and decrease efficiency in industry."*
>
> *American Committee on Optics & Visual Physiology*

There were also some other techniques like warming one eye, electrical stimulation, injections of iodine or extracts of cobra venom, vitamins or flashing light. All this finally resulted in an official statement of different Academies and Medical Associations that *no method had been found for the correction of color blindness, whether called 'color weakness', 'color confusion' or 'color defectiveness'*—which is still true as of today.

But there were also some good ideas around like color filters or spectacles with horizontally divided red and green sections.

6.2 Aids for colorblind people

If you have a closer look at the available tools for color deficient people, you have on one side the computer and all its possibilities and on the other side non-computer based aids.

On the non-computer side there is actually just one technique used: **colored filters**. These filters come in different forms:

- **Lenses:** Manufacturers of tinted lenses claim that their product can improve color vision for colorblind users. And people often read this as if they could almost cure your color blindness—which is wrong. Here are some facts about tinted lenses:
  - They have to be worn in only one eye, as otherwise fewer colors are seen.
  - It needs some time to get used to them and *learn* some *new* colors.
  - They can help you and enhance your color perception in certain situations.
  - You want be able to see *more* colors, but maybe other ones then you are used to.
  - Certain colors seem to vibrate or shimmer because of the usage in only one eye.
  - Worn while you are driving they can be a safety risk because of the worse perception at dim light situations.

- **Glasses:** It is almost the same for colored glasses as for lenses. The first products looked a bit strange as only one glass is tinted. Recent products have some coating which reduces this effect and makes glasses a true alternative for the lenses.

- **Tools:** There is a little tool called Seekey which is made of two tinted filters, one in green and the other in red. If you look through the filters on and off you can definitely distinguish more colors as a colorblind. This can be an advantage for some specific tasks in certain professions or in some everyday life situations. Such filters can also enhance certain diagnostic or medical instruments and help the colorblind operators to see what they otherwise wouldn't spot that easy.

Many colored filters can help you to pass some color blindness tests, specially the famous Ishihara plates test. But this is not the correct purpose as those tests are usually there to assure, that your color vision isn't a safety issue. Because of that in most cases tinted filters are not allowed to be used on such qualifying tests.

If we have a look at the **computer based helpers for colorblind users**, there are different tools available. Those tools make use of different techniques which can only be done digitally.

- Show the name of a color if you point to it.
- Shift the whole color spectrum around the color wheel.
- Highlight certain specific colors in a different color.
- Use a pattern to highlight certain tints.
- Some sophisticated algorithms which try to manipulate a picture to the effect that colorblind people perceive it still as *normal* but that certain shades can be better distinguished.

Such tools might really help you in some specific situations but often they are not that easily adaptable and sometimes just too cumbersome to handle. And don't forget that all those tools can only be used while working on a computer, which is in everyday life often not such a big handicap for colorblind people.

6.3 Cure of color vision deficiency

As mentioned in the lead of this article there is **to this day no cure for colorblind people available**—but it looks like as if there is one for colorblind monkeys!

Jay Neitz, a well known vision scientist, and his team developed a gene therapy to enhance color vision. Colorblind monkeys were used as test animals. They received the gene injections directly into their eyes to build up the missing color receptor.

The monkeys had to perform a color blindness test and if they did well they received a reward. After a while they started to perform much better on a task they couldn't accomplish before because of their vision handicap.

Monkey performing a color blindness test

Due to this test result many colorblind people hope to be able to get rid of their color vision deficiency in the near future. Unfortunately this wont come true that fast. And there are some difficulties which have to be overcome until this dream could get true:

- Gene therapy for red-green color blindness may not work in humans as well as it does in the monkeys.
- Side effects of subretinal injections can include irritation or infection, in addition to the risks of permanent retinal detachment and blindness at the injection site.
- There could be adverse psychological effects associated with suddenly being able to see new colors and learning how to categorize them.

Also other institutions started to pick up this topic and are looking into the development of such a gene therapy to *heal* congenital color vision deficiency.

There is a possibility that a color vision handicap can disappear again. In some cases of acquired color blindness, especially for vision deficiencies which can occur after a hard hit on your head, it is reported that this handicap can disappear again after a certain time. Unfortunately this can't be influenced and the process of healing can't be used for all other colorblind people.

*Thanks for reading this eBook on **COLOR BLIND ESSENTIALS** and I hope you enjoyed it. Please also consider checking the Colblindor website at www.colblindor.com and share your thoughts, stories and ideas or ask your personal questions at the color blindness forum. You are also welcome to try some of the tools or the online color vision deficiency tests available directly on Colblindor.*