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A CONTEMPORARY REVIEW OF GENETICS, EPIDEMIOLOGY AND DIAGNOSTIC INSIGHTS INTO RED GREEN COLOR BLINDNESS

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Abstract

Red green color blindness is also called red green color vision deficiency. This is a common visual deficiency in people who have difficulty seeing the difference between red and green colors. The term, color blindness refers to the people who can see color but they don't know what the color is. For example, many people see red as green, brown as gray, and green as yellow. This disease is a genetic disorder present from birth. In most cases, it is caused by abnormalities in the color-sensing cone cells of the eye. Normal color vision mainly depends on the type of cone cells in the retina of the eye. These cones are sensitive to blue, green, and red light. The brain combines them to create a full range of color we see. Red–green color blindness happens mainly because of problems in the red (L-cone) or green (M-cone) cells. The probability of having red green color blindness is higher in men than women with about 8% of men and less than 1% of women affected by this kind of genetic disorder. These problems are linked to gene locations on the X chromosome which explains why men are affected more than women. This difficulty can affect learning and daily life activities especially in the schools where colors are used in books, charts, and teaching materials. A child with color blindness may struggle to understand lessons that depend on colors. Colorblindness can limit job choices such as pilots, electricians, doctors, engineers and designers which require accurate color recognition. Over time, scientists have tried different ways to classify red green color blindness. Research shows that color blindness is not same for everyone.

INTRODUCTION

This defect is not accurately described as colour blindness. Colors are clearly seen and perceived as such in the common varieties, but there is insufficient ability to distinguish between them. For example, reds are confused with greens and greens with reds. For example, a person picked a red-hot coal, a colour-blind mailman said, "What funny green thing is this?" When his fingers came into contact with the coal, he didn't need a reply. (Liang, 2005). The case of the eminent chemist, Dalton's was the first to bring colour blindness to the public's attention. Dalton actually wore the red robe of a doctor of civil laws at Oxford for several days after receiving it, happily unaware of the impression it made on the people. When asked what the horrible scarlet gown he was wearing resembled, he pointed to some evergreens outside the window and remarked that the colors look same to him. He claimed that the gown's pink lining looked sky-blue to him. Another example, explains that when soldiers wore scarlet jackets, a soldier removed his coat and placed it on a hedge. When he wanted to put it back on, he couldn't find it, even though it was the most noticeable thing in the area to others.

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Recognizing red flags on a green background from a distance is a challenge for many colour-blind golfers. Because the color of cherries and strawberries is comparable to that of their leaves, people who are color-blind frequently become aware of their condition as young children (Doidge, 2024).

PREVALANCE OF COLOUR VISION DEFICIENCY:

Almost 8% of men and 0.5% women suffer colour perception insufficiency (CVD), which makes it difficult for people to perform colour-related visual tasks (Sun & Ma, 2025). For any of the three cones, observers with CVD display an abnormal photopigment absorptions spectrum. The reason is a change in the photopigments absorption peaks of the abnormality in colour vision, according to substantial evidences. (Doidge, 2024).

TYPES OF COLOUR VISION DEFICIENCY:

The kind of photopigment determines the change in the absorption spectrum in situations of anomalous trichromacy; protanomaly, deuteranomaly, and tritanomaly are represented by anomalous L-, M-, and S-cones, respectively. In dichromacy, one photopigment is absent or replaced by another type. (Yong Tao2 & Liang Jia, 1802). Monochromacy is a rare type of colour vision deficit that results in severely limited colour perception when either no functional cone photopigments are present or just one type of photopigment is available Compared to other forms of colour vision abnormalities, this disorder is rare and is usually linked to severe chromatic discrimination difficulties (Lijian Sun & Shining Ma, 2025).

GENETIC BASIS:

The amino acid sequences of long wavelength and medium wavelength cone opsins are extremely similar, sharing 96% sequence identity and differing by just seven amino acids within their photopigment genes, according to molecular genetic studies However, as compared to short-wavelength cone opsins, these L and M cone opsins exhibit significantly less similarity, about 46%, indicating clear functional and evolutionary distinctions among cone types(Almutairi, 2025).. This area is especially vulnerable to uneven crossover and recombination events during gamete production in females due to the near physical closeness of the L and M cone light sensitive protein genes within the same genetic locus By changing the structure or expression of cone photopigments, these genetic rearrangements are crucial in the development of red-green colour vision impairments (Sun & Ma, 2025).

CLASSIFICATION OF RED-GREEN COLOUR BLINDNESS:

Red-green colour vision impairment contains both deuteranopia & deuteranomaly, which mainly entails M-cone malfunction, and protanopia and protanomaly, which affect L-cone function. These conditions account for most hereditary colour vision impairments found in human populations. On the other hand, because of shortage of physiological data, which involves S-cone pathways and are frequently thought to be acquired or autosomal in origin, these conditions are rather uncommon and have been left out of the scope of this work. Human colour discrimination depends on light of different wavelengths differentially stimulating three types of cone photoreceptors, also known as red, green, and blue cones. A person may have poor colour perception if more than one cone type are abnormal, making it difficult for them to distinguish between certain colors (Yong Tao2 & Liang Jia, 1802).

AWARENESS AND DIAGNOSIS IN CHILDREN:

Children which are born with color blindness they do not realize that they have this disorder. Because of this, students frequently adjust naturally and might not be aware of their limitations until they come across tasks that significantly depend on precise color identification Because color vision loss might limit future educational and career options, early screening for the condition is crucial. People with colour blindness have a disadvantage compared to normal people in a number of countries where they are barred from occupations like electrical work, chemistry, law enforcement, aviation, and visually demanding creative fields. Red-green color blindness is more common in males than females, according to epidemiological research done in populations of

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European ancestry. With an estimated prevalence of roughly 5%, deuteranomaly has been found to be the most prevalent subtype among these instances; deuteranopia, protanopia, and protanomaly each account for about 1% of cases (Lukas, 1999).

1. Physiology of color vision, material and methods:
One hundred and thirty men were studied in this experiment out of which 64 were confirmed color blind were confirmed by using color vision test. The participants then were divided into two groups. The first half of the group were tested with colors while the other half associated with patches. The participants who were in this experiment was from Switzerland and they were mostly students and staff members. There was no significant difference between their ages although research shows that only a small number of participants were needed. The participants included different types of people: the people which were better at studies, and the people which were better at games, or the people which were better at different sports, to identify how people response to the color blindness. The people who participate in this method received a reward of CHF 20 in gift vouchers (Athanasopoulos P, 2021).In the experiment, twelve colors were used as stimuli: red, orange, yellow, green, blue, purple, pink, brown, white, gray, black, turquoise. Eleven of the colors represent the main category while the turquoise was added to represent the color between green and blue. In one condition, the color was shown as French color names, while in other condition, actual color patches were shown. The color patches were introduced meaning that patients who were diagnosed with red green color blindness scientists studied them and the experiment clearly represent each color category. These color patches were also used before in the studies with French speaking participants in Switzerland (Domicile J, 2021).

1.1 The importance of the colour system:
Schietecat and colleagues studied that how color combinations affect emotional reaction. They explain that emotions have different types, based on whether something feels good or bad whether we feel excitement or disturbance. Using tests, they quickly measured unconscious responses that the color red change depends upon the color, it compares with. When red is compared with green people linked it more with strongly negative feelings rather than positive. On the other hand, when red is paired with blue. Many people linked it with energetic or excited perspective. Their experiments show that color does not have a fixed emotional meaning they depend on the other color around them. Their hypothesis shows a touch in real life activity. Because the color is usually seen together not alone. They explain that a color system usually means using the same color together again and again in one context over time they said that a color can feel different when seen (Kawai, C 2023).

1.2 Color vision in high diversity of arthropod:
Arthropods use light-sensitive protein for vision although many living organisms. They use different pigments to see light, such as phytochrome as cryptochrome. Animal visions depend on opsins. Opsin work by binding of vitamin A molecule and a light sensitive receptor. Arthropods have r- opsin in photoreceptor cells, while vertebrates use a different type ciliary opsin. Many vertebrates have only one visual r-opsin while the ancestor of arthropods is believed to have five different visual r opsins. The arthropods also contain other opsins that are expressed in the brain, such as peropsin and pteropine. Arthropod opsins have rapidly evolved, resulting in a high degree of variety today. While some species, like deep-sea crustaceans, only use one opsin, others contain extremely high colour vision systems. For example, some mantis shrimps express up to 15 different opsins in their eyes, while dragonflies contain up to 40 opsin genes (Ayse Y, 2022).

2. Epidemiology and Clinical Significance
The frequency of red-green colour vision in an older population over 60 years of age:
This study was done in a careful and ethical way. The people who were included in this study agreed willingly and they signed written permission before the experiment. The study follows international ethical rules which were approved by Health Ethics Committee in Iran. This study was part of Tehran. This study was carried out in January 2019 to January 2020.This study mainly focus on people who were 60 years old or older. Participants were chosen

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randomly from all the part of the city; researchers visited homes and invited elderly people to join in order to complete the experiment. Those people who joined the experiment was given free medical checkups and their personal information was kept private at the Research Center (Mahdi K, 2023). The participants were first asked simple question about their age, health, and medical history. Then, they tested their vision. Doctors want to check that if they could see far and near clearly. First, they examine the patient with glasses on and then without glasses. Their color vision test was performed by using a special picture which contained hidden numbers and colored dots. Doctors examined both front and back parts of the eye to make sure that the patient who was participating in this experiment was healthy. The people who were part of this experiment or study was first examined the patient had surgery before or contain very poor eye vision was not included. In this experiment afterward the result was analyzed. The doctor found out that color blindness problems were also related because of age and by diseases (Hassan H, 2023).

2.1 Clinical Purpose

2.1.1 Gold nanocomposite Contact Lenses to Treat Colorblindness:

For a long time, gold nanocomposite and gold nanoparticles were used for optical light related purposes. As early as, 1802, goal nanoparticles are used to make glass and these glasses are called red Ruby glass. The glass is also made still today. Recently researchers find that adding gold and silver to nanoparticles and then the contact lenses change how light passes through them. They explained that the lenses were soaked in solutions cleaned, and then tested. These total lenses show properties filtering similar to nanoparticle solution themselves. These lenses were designed to help people with retinal problems or the people who cannot see clearly or those who feel difficult to see in the very bright light. Gold nanoparticles are also mixed with plastic to make color filters. When this mixture is stretched in one direction their color changes depending upon the direction of the light this process happens when the direction or arrangement of nanoparticles changed. This material is also called as special color filters which can react to polarized light. Gold nanoparticles were built directly in the contact lenses which can block certain light wavelengths that are hard for people with color vision deficiency (CVD). They first study the size, and the shape, of the nanoparticles using microscope and measure how they can absorb light. They tested in different surroundings. They also test that the nanoparticles affect the water content and comfort of the lens. Unlike dyes nanoparticles are inside the lens and are more stable. This explained that if these lenses can perform well during the experiment, they could be a better alternative to dyes for making contact lenses that help people with color vision blindness. For example, red green color blindness (Salih, A 2021).

2.2 An Evaluation of Colour Blindness in Daily Life

In this experiment people of different ages and genders took place. This makes the result more reliable than ever. Because the majority of the participants were young, awareness about color blindness is very important because it was the time when people choose their careers men and women were almost equally represented, this is very useful because the ratio of color blindness is higher in men than women. More than the half of the participants live in rural areas where healthcare and eye testing is often limited. In order, to improve awareness about color blindness awareness program focus on rural communities and use simple language to communicate with the people to spread knowledge about color blindness. Most people knew that the color blindness is a genetic disease and cannot be cured and they also knew that eye doctor is the right person to consult in order find cure about this disease. Although, people understand that how color blindness affect their daily lives such as difficulty telling difference between red and green color apart. This can also cause problem in schools or during work. Some people also lack knowledge about basic eye health like the role of vitamin A in Retina. They lack the awareness about color blindness that this can cause a series problem especially when people choose career in field like defense, railway, healthcare, or electrical work. These are the works where good color vision is required. Without good color vision, it can become dangerous for them or for others. Without its awareness people may face

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disappointment later in life. Teacher may also fail to recognize students who struggle because of color blindness rather than poor learning ability. This study mainly suggests that color vision testing should be done in schools, especially for boys because the ratio is much higher in them. Public awareness programs should explain real life problems caused by color blindness by using simple examples like pictures and local languages. Healthcare workers should also be aware about color blindness in order to guide other people properly about the consequences and challenges of color blindness (Joshi, A., 2025).

3: A NEW CLASSIFICATION OF RED AND GREEN COLOUR BLINDNESS:

3.1. Protanopes and Deuteranopes: People who are Protanopes and Deuteranopes have difficulty seeing colour. The terms Protanopes and Deuteranopes were used by von Kries. This is what von Kries did to explain Protanopes and Deuteranopes. The difference is something that most people agree on even if they have different views about how we see colors. People with deuteranopia, see colors mostly based on blue and yellow. They can still perceive colors, but with limitations. People with protanopia or red-blind people also see colors using blue and yellow. They have a hard time seeing red. For people with protanopia red looks dark. People with protanopia see colors differently because of how color vision works. People usually agree on this way of grouping colors. (Terman, S. W. 1928).

3.1.1 Edridge-Greens Classification:

Edridge-Green, the person who made the lantern test to check for color blindness found a way to group people. He developed a system, which is called Edridge-Green's Classification to group people based on how they see colors. Edridge-Green's Classification is a way to understand how people see colors differently. He did not focus on what colors people cannot see. Instead, he looked at how well a person can see colors. People who have vision are called trichromats. This is because they can see three cones type of cell. Some people are color-blind. They might be dichromats, which means they can see two colors. Then there are some cases. These people are called monochromats. Monochromats can perceive only light and dark, with no discrimination (colour) Color-blind people, like dichromats and monochromats do not see colors, like trichromats do. Edridge-Green thought that color blindness is about losing the ability to tell colors apart rather than completely losing the color sense of the colors. This is what Edridge-Green thought about color blindness and how it affects the way people see colors. The system he created looks at how good peoples are doing things that need color. This is really important for jobs where you need to know colors. Even though not everyone used his system of grouping color blindness it helped people see that color blindness can be a problem or a big one (Lanthony, P. 2018).

3.1.2 Ishihara's Classification:

Ishihara, a scientist, developed, a test to check for color vision problems. This test is well known. Ishihara's Classification is about color vision problems. Ishihara agrees that we should separate red color blindness and green color blindness. The work that this person did shows that some people who have trouble telling the difference between green colors also have trouble with blue and yellow colors. However, this is not true for all people with this problem. Ishihara Refers to individuals with severe color vision defect (Hairol, M. I. 2025).

3.1.3 Collins Findings: Collins did a study on people with green colour blindness. He wanted to know what these people really see. Collins looked at ten people who have this problem. He tried to understand what colors are like, for them. Collins did not use any ideas that other people had about color vision. He just wanted to know what these ten people thought about colors.

3.2 Main classification: Colour blindness is a genetic disorder where people have trouble seeing red and green color. It is mainly classified into the following types: (Protanopia, Protanomaly, Deuteranopia, Deuteranomaly).

Protanopia occur when L-cone is absent in the eyes. This means that red things look really dark or even black to them. People with Protanopia have difficulty telling the difference between the colour red and the colour green (von Kries – late 1800s)

Protanomaly: The red cones in the eyes are present. They do not work properly. When people with

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Protanomaly look at the colour red it seems dull or weak to them. This is a form of protan defect, which affects how people see the colour red. Protanomaly is like a version of a bigger problem, with seeing red colors.

Deuteranopia is a condition where a person has an absence of green cones. This means that green colors are not seen properly by people with Deuteranopia. For people with Deuteranopia, red and green condition appear very similar to Young–Helmholtz theory. Deuteranopia makes it hard for people to see colour (Ewald H, 1878).

Deuteranomaly: Green cones are abnormal but present. Most common and mildest form of red–green colour blindness.

4. Cutting-Edge Treatments for Color Vision Deficiency

According to research, 4.63% of individual have deuteranomaly and 1.08% of peoples have protanomaly. Another type of colour weakness occurs when a person struggles to distinguish between blue and yellow, this condition is called tritanomaly. Similar to red-green weakness, this condition becomes worse in low light and gets better in strong light. This condition has a lower prevalence, affecting approximately 0.2% of the persons. In general, approximately 8.98% of people are considered to carry color vision gene. Colorblindness commonly found in males then females. The ratio is higher in men than women. Complete colour blindness is exceedingly rare, occurring in about 1 out of 30,000 people, but red blindness, green blindness, and blue-yellow blindness occur at lower but measurable rates (Salih et al. 2020).

4.1 Possible advantages of colour vision aids for varying degrees of colour vision impairment:

4.1.1 Real-world scenario:

The majority of colour vision diagnostic tests involve illuminant stimuli, and passing this test require threshold colour discrimination. Real-world tasks that depend on colour identification rarely function at the absolute threshold of human colour vision, even though anomalous trichromats may be able to distinguish the functional colour differences. In order to evaluate the colour discrimination of individuals in relation to a real-world scenario, we tested the model using a vivid image of a hot air balloon. A helpful foundation for comparison is provided by the individual squares in different shades of red, green, blue, and yellow. (RACHEL B, 2022).

4.2 A new benchmark for the clinical identification of colour vision impairments is genetic testing. Topic: Hiring

Total 1074 people were selected for color blindness test. Fourth edition HRR assessed the patients. The persons or patients who participated in the color blindness test was given more colors to identify how bad their blindness is or how severe their blindness is such as the Nagel anomaloscope. DNA was used. They extracted DNA from the blood and saliva to identify color blindness to study the cone opsin gene. DNA Sample form 798 patients were supplied to the Medical Center for research (Camden, NJ). Since they were not selected for colour vision, these patients are believed to be representative of the overall population in terms of the prevalence of genetic colour vision issues. Samples were tested before being sequenced. Psychophysical colour vision could not be assessed. The patients were given results about their condition. The institutional Board at the Washington DC approved the experiment of human testing vision color blindness (Candice D., 2016).

5. Why Can't You See Red and Green? Analyzing Color Blindness Simulations as Resources for Developing Chromatically Accessible Games

5.1 Upcoming difficulties and hues in video games:

Although future games are complex, it is very necessary to provide accessible player experience for all users (APX) so that the level of difficulty is appropriate for all players. Although the color blindness is a problem. During the games, many players or competitors provide the data that they face problems while playing visual games Participants, explained that the main difficulty, they face while playing the visual games is the color differences, whether they are used to differentiate teams in simpler situations or as essential elements of the primary game mechanics. After examining, how the colors affected player's emotions and performance, Wolfson and Case came to the conclusion from their study that blue cause a steady increase in reaction,

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whereas red produced a more explosive reaction with a peak in performance at the start of gameplay. Additionally, Napoli and Caisson created an experiment to see how color blindness affects participants' performance in a light-hearted game. Although, there were no appreciable changes in their performance, the participants stated that they believed their performance had decreased as a result of the simulation (Mateusz P, 2023).

5.2 Providing Red-Green Colorblind People with Accessible Packaging Method:

This study employed VDS to mimic red-green colorblindness in order to determine which items in a retail context could be difficult for colorblind customers to read or recognize. Members of the research team wore these glasses as they perused the aisles of a local supermarket to identify any products that were difficult to see. After a product was identified, the researcher asked at least three other team members to evaluate it with the spectacles and let them know if they agreed with the assessment. The research team restricted the number of products to six based on consensus which were the most challenging to comprehend while wearing VDS. After gathering a number of packages and items that they found problematic. Images taken both conventionally, and via the lens of the spectacles were provided in the documentation for each product. The Colgate Optic, White Pro Series, Toothpaste box, was chosen to undergo a redesign process in order to improve accessibility. Maintaining the hue red, which is essential to the product's overall branding, while making the box more accessible for Red-green colorblind consumers. Adobe Photoshop and Adobe Illustrator, two commercial image editing programs, were used to digitally generate the redesigns once they were first sketched out. VDS was utilized throughout the design process to make sure the redesigns met the objective of being comprehensible to people who are red-green colorblind. In order to precisely recreate a completely modified packaging, the new design was finally printed and trimmed to the shape of the previous box (Cavender, 2024).

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