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# **Colour Vision** Defects

A Factfile provided by the Institution
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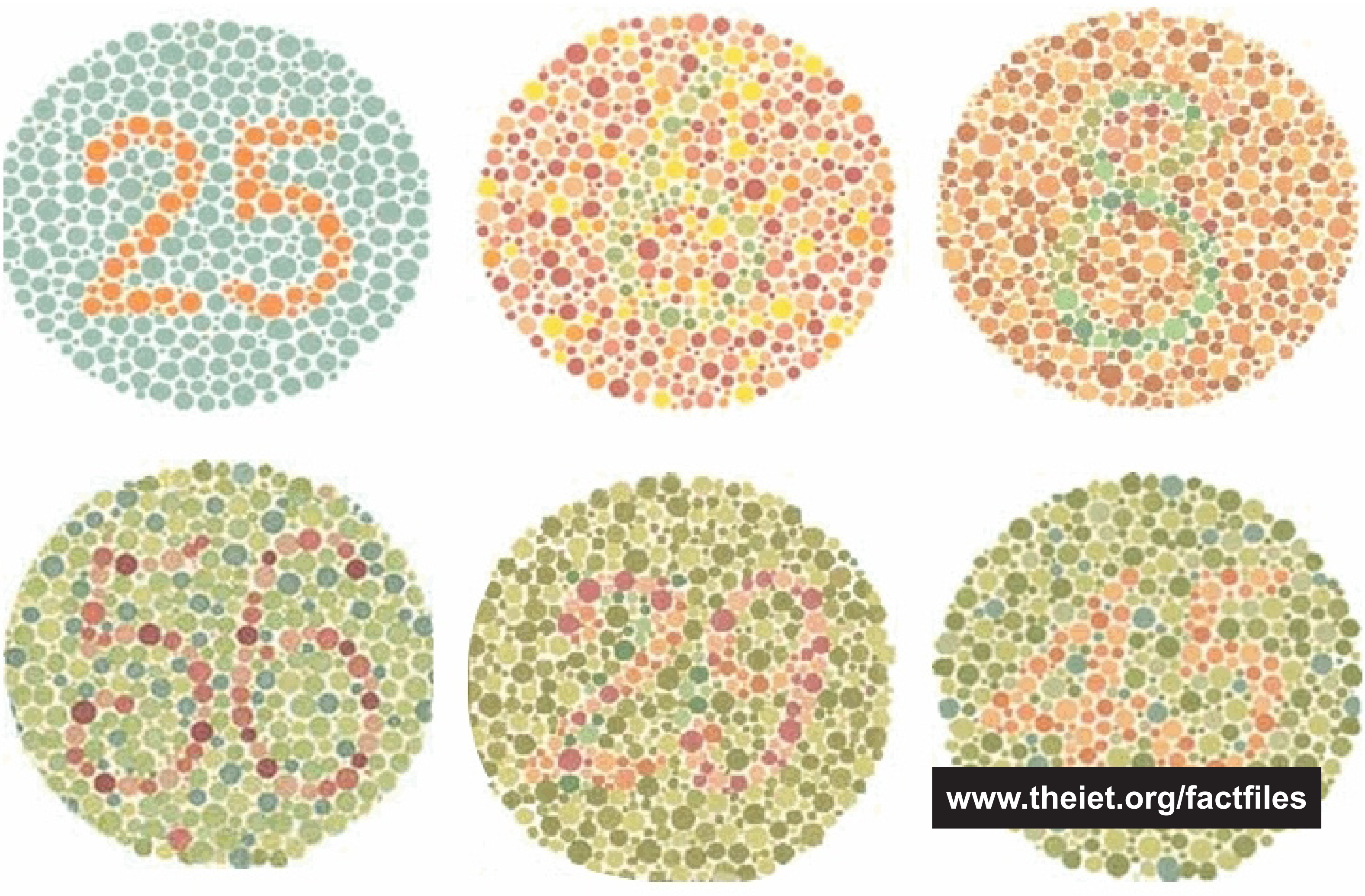

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## About This Factfile

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## What is this factfile about?

Approximately 1 in 12 men and 1 in 200 women suffer from some form of defective colour vision. The degree of disability varies widely, and can even be so severe as to preclude an individual from pursuing certain careers.

Complete “colour-blindness” (i.e. the perception of the world in monochrome shades of grey), however, is very rare.

This fact sheet answers some of the common questions asked by people who think they may have some form of colour vision defect, as well as those asked by employers.

## What is colour?

What we know as "light" is a small part of the electromagnetic spectrum. The electromagnetic spectrum is categorised by the wavelength or frequency of radiation and includes radio waves, microwaves, ultraviolet light and X rays.

The visible spectrum (light detected by the human eye) encompasses radiation from approx. 400 to 700 nanometres (nm) in wavelength. This gives the familiar rainbow of colours, from violet at around 400 nm through green to red at around 700 nm. White light (e.g. sunlight) is a combination of all visible wavelengths of radiation. Most materials absorb some wavelengths of light and reflect or transmit others. An object made of such a material looks coloured when illuminated with white light, because only the reflected/transmitted wavelengths remain. For example an apple looks red because all wavelengths are absorbed by the apple skin except for radiation around 700nm.

## What is "Defective Colour Vision"?

The brain perceives colour from the combination of responses from the three receptor types in the eye, when exposed to light. The receptors are cone shaped cells on the retina of the eye that contain pigments. The pigmentation of a cone type makes it more responsive to light in the red, blue or green part of the visible spectrum. Beyond the retina, the signals are converted from a chemical into an electrical form and transmitted to the brain for interpretation.

Colour is perceived from the combination of responses from the three cone types. Defective colour vision results from either a lack of one colour receptor or a change in the way in which the receptor responds to particular wavelengths ( i.e. the peak sensitivity is shifted).

The extent to which an individual's colour vision is defective can vary enormously along a scale from mild deficiency to total lack of colour vision (true colour blindness).

Mildly affected individuals have difficulty with pale colours and with darker hues, but colours will only be confused if they are of exactly the same brightness. If one receptor type is missing and therefore cannot respond to any wavelength, a severe form of colour vision defect results. Severely affected individuals have difficulty even with bright colours although again, they can differentiate colours if they differ in terms of brightness.

Defective colour vision is usually inherited, although it can be acquired as a result of eye disease, or as a side effect of medication or toxic poisoning. Acquired colour vision deficiency is very rare. Sufferers are frequently blue/yellow defective, which means that they cannot be tested for using some standard procedures such as the Ishihara plates.

Defective colour vision can have an impact on many everyday activities, dependant upon the type and severity of the defect and the lighting conditions. These include distinguishing the ripeness of fruit, reading maps, and choosing clothes. Sufferers cannot distinguish as many different colours, they confuse certain colours (if equal in brightness) and depending on the type and severity of defect, they may have reduced ability to see red (it will look dark), which has implications for driving (stop lights, brake lights) because of increased reaction times.

## Terminology

The common term is "colour blindness", however this is misleading due to the wide variation in deficiency experienced. The medical terminology appears at first sight to be quite complex and is loosely based on Greek:

**Table 1: Types of Colour Vision Defects**

| **Terminology** | **RED** | **BLUE** | **GREEN** |
|---|---|---|---|
| Trichromatism (Normal sight) | Can differentiate all colours | | |
| Anomalous Trichromatism | Can differentiate all colours but one colour has reduced or displaced sensitivity | | |
| Protanomaly | Displaced sensitivity | | |
| Deuteranomaly | | | Displaced sensitivity – most common colour vision defect |
| Tritanomaly | | Displaced sensitivity | |
| Dichromatism: | | | |
| Tritanopia | Receptor normal | Receptor missing | Receptor normal |
| Deuteranopia | Receptor normal | Receptor normal | Receptor missing |
| Protanope | Receptor missing | Receptor normal | Receptor normal |
| Monochromatism (Achromatopsia) | Totally unable to differentiate colours of equal brightness | | |

Most colour defective people in the UK are anomalous trichromats, which can vary in severity from very mild to almost dichromatism. Deuteranomaly, the displacement of green sensitivity, is the most common type. This results in difficulties differentiating between reds and greens and between blues and purples.

Dichromatism is not as common as anomalous trichomatism. Monochromatism, the inability to differentiate any colour, is very rare and is usually accompanied by poor general vision.

## How Do I Find Out if I Have Colour Vision Defects?

If you experience problems in distinguishing colours, in comparison to other people, then you may have defective colour vision. It is common for people with a mild deficiency not be aware of it. The condition is genetically inherited from your mother, so if someone in your family has defective colour vision (particularly a maternal grandfather or a brother), then there is a possibility that you, and your children, may also be affected. The best advice is to establish first of all if there is a defect. Your doctor or optometrist can test if you have defective colour vision, and arrange for further tests to establish the degree to which you may be affected. It is particularly important for children to be correctly diagnosed, as they may experience difficulty with colour coded materials used in schools. Early diagnosis is also desirable in terms of choosing a career.

The most common screening test uses Ishihara plates. The Farnsworth D15 test and the City University test are used to establish the type and degree of deficiency. However these tests only provide some information regarding the type and degree.

## What Jobs Can I Not Do?

Many jobs require the ability to distinguish between colours, either implicitly or explicitly. Whether or not an individual with colour vision defects is capable of doing a particular job depends on the degree of the defect, and the importance of accurate colour distinction to the job function. Many employers are re-evaluating their colour vision policies following the introduction of the Disability Discrimination Act.

The following list shows the careers that require non-defective colour vision. The requirement for those involved with transport to have non-defective colour vision is clearly consistent with their job function, in which the ability to distinguish colour coded signals and navigational aids is essential to ensure passenger safety.

Careers and occupations known to require non-defective colour vision:

- Armed Services (some branches)
- Customs and Excise Officer
- Civil Aviation – pilots (under review), engineers, technical and maintenance staff, air traffic controllers
- Railways - drivers, engineers and maintenance staff
- Fire Service Officers (mild deuteranomalous allowed)
- Hospital Laboratory Technicians and Pharmacists
- Workers in paint, paper and textile manufacture, photography and fine art reproduction

Obviously a job that requires accurate matching of colours, for example in the dye industry, would be unsuitable for an individual with even mild discrimination problems. Likewise, in the electrical and electronics industries, the ability to identify the colour coding of cables, wires, resistors and capacitors, in different ambient illumination conditions, is required.

Not all employers test for non-defective colour vision, and those that do sometimes use only a simple screening test, which may exclude mildly affected individuals unnecessarily.

From the viewpoint of the individual with defective colour vision, it is not advisable to enter into employment where colour discrimination is an important factor, in case it affects career prospects in the future. On the other hand, there is no point in ruling out a particular career if the disability is mild and manageable. The crucial first step is to establish the degree of disability, and then make a decision.

## What Can I Do About It?

Unfortunately, defective colour vision has no cure. There are, however, a number of things the individual can do to minimise the impact it has on everyday life. Many sufferers find alternative identification methods to get around problems e.g. textures or shapes. A coloured filter, carefully chosen to emphasise the dark/light differences between the colours being confused, can allow some colour tests to be passed. This filter can actually be incorporated in contact lenses, (it looks strange in spectacles) but these are not recommended for continuous use. It should be noted that such filters can cause problems with binocular vision and coordination. They simply shift the colour defect to another area of the spectrum resulting in different colours becoming confused instead.

Good illumination levels also aid colour discrimination, the preferred source being natural indirect sky light. Failing that, colour corrected fluorescent tubes, as opposed to tungsten filament lamps, can help with colour recognition. If in doubt about colours, (and it is important to get it right) ask for advice from someone who has non-defective colour vision.

## What Does it Mean to an Employer or a Manufacturer?

Realisation of the probable existence of colour vision defects among staff is the first step a responsible employer should take. Thereafter there are several aspects to consider:

- What are the consequences of an employee making a mistake in colour identification?
- What steps can be taken to make mistakes less likely?
- Is it worth testing prospective employees?
- Could the company be liable for redundancy payments if an employee was found to be incapable of reliably performing the task for which they are employed?

These questions can only be answered by the company itself.

A product manufacturer must also realise that some of his customers will have defective colour vision. Again, recognition of the existence of the problem is the first major hurdle. There are a number of steps that can easily be taken to improve matters in cases where correct colour discrimination is important. Choice of colour, differences in brightness, and the shine on a surface finish, can all significantly affect the ease with which colours may be distinguished.

The colour coding of light signals and of electrical components is nominally controlled by British Standards. The tolerance is usually specified but can be quite broad. Variation within the tolerance, and in the case of electrical components the background colour, can lead to misidentification.

## The Costs of Getting it Wrong

There are numerous examples of substantial costs being incurred through mistaken colour identification: for example, the cost of a day's production of resistors discarded because of incorrect colour coding; a length of carpet woven with an incorrect colour thread; fruit picked too soon when not ripened.

Consequences of inaccurate colour distinction can, however, be far worse, as past incidences have demonstrated. When mistakes in the colour identification of signals in shipping and railways have occurred, accidents have involved the loss of life.

Given the compulsory tests for train drivers and pilots, the impact of defective colour vision on the average car driver seems obvious. The studies undertaken to date show that those who have difficulty distinguishing red, (protans) are more likely to be involved in accidents, such as rear-end collisions and failure to stop at traffic lights, than people with non-colour defective vision. Some countries even go so far as prohibiting people with defective colour vision from jobs as public service vehicle and transport drivers.

## The Special Perspective of the Electronics and Electrical Engineering Industries

Colour coding is widely used in the electronics and electrical engineering industries, and has particularly significant safety connotations.

Colour coding is used to differentiate the value of resistors and capacitors. In the telecommunications industry, extensive use is made of colour coded wires. Errors in identification could have serious consequences.


## The IET would like to thank:

Dr Catharine Chisholm of the Applied Vision Research Centre, City University for her help in compiling this fact sheet.


## Further reading:

If you would like to read in more depth about this subject, the books below give a comprehensive overview, from the perspective of an optometrist.


- Birch J; Diagnosis of Defective Colour Vision; Oxford University Press; 1993

- Fletcher R & Voke J; Defective Colour Vision; Adam Hilger; 1985


## For a general introduction to the topic:


- McIntyre D; Colour Blindness Causes and Effects; Dalton Publishing; 2002


## Further Information

The IET produces a number of briefings and additional information on health and safety:
http://www.theiet.org/factfiles/health/index.cfm