



Colour vision examination

A guide for occupational health providers

Guidance Note MS7 (Third edition)

This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

1 This document acts as an aid to employers and their occupational health providers in choosing the appropriate colour vision testing methods given the risks involved in the occupation. The incidence of colour vision defects constitutes approximately 8% of the male population for both inherited defects and a similar number for acquired defects, especially in those over 45 years of age. Employers and occupational health providers should also realise the importance of using a risk assessment-based approach when deciding what the pass/fail criteria is for employing a person, where colour vision is a requirement of their employment. This should be decided before starting any colour vision testing procedure. Occupational health providers may find it useful to read this document alongside *Colour vision examination: A guide for employers*.¹ If an employer has employees whose colour vision is important for safety-critical purposes, then colour vision testing is crucial in deciding on their fitness for work. However in companies where colour vision needs are not associated with safety-critical systems but with product quality, colour vision testing is valuable to avoid costly errors.

TYPES OF COLOUR VISION DEFECT

2 Retinal cone cells contain three classes of photopigment that have maximum sensitivity in the long-wavelength (red), middle-wavelength (green) and short-wavelength (blue) parts of the visual spectrum. In those with normal colour vision, this is referred to as normal trichromacy. Inherited colour deficiency arises from inherited cone photopigment abnormalities. There may only be one photopigment (monochromatism) or two photopigments (dichromatism) in the retina instead of

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three. Alternatively, although all three photopigments are present, there may be abnormal spectral sensitivity (anomalous trichromatism).

Monochromats

3 Monochromats are individuals who have single-cone photopigment-type cells, or no functioning cone cells at all. Visual acuity (sharpness) is poor and this type of colour vision defect is usually identified in early adulthood. Colour discrimination is not possible and people are truly colour blind, seeing everything in shades of grey and white. The incidence of this defect is very rare for both inherited and acquired defects.

Dichromats and anomalous trichromats

4 Dichromats are deficient in one of the three colour receptor mechanisms, due to a cone colour pigment deficiency. There are three types of dichromatic colour deficiency, protanopia (red), deutanopia (green) and tritanopia (blue), depending on which of the three photopigments is affected. Protan and deutan defects are known collectively as red-green colour deficiency. Anomalous trichromatism is where the spectral sensitivity of one of the three colour receptor mechanisms is altered. This defect is seen in both acquired and inherited subjects and there is a wide spectrum of severity. The classification system and terms used are shown in Table 1.

Table 1: Terms used to describe dichromats and anomalous trichromats

	Protan defects: Abnormalities of the red-sensitive photopigment	Deutan defects: Abnormalities of the green-sensitive photopigment	Tritan defects: Abnormalities of the blue-sensitive photopigment
Dichromatism	Protanopia	Deuteranopia	Tritanopia. Rare for inherited. Common for acquired
Anomalous trichromatism	Protanomalous trichromatism	Deuteranomalous trichromatism	Tritanomalous trichromatism

Colour genetics

5 Genes that specify the red- and green-sensitive photopigments are located on the X chromosome and abnormalities are inherited as an X-linked recessive trait. This results in a much higher prevalence of red-green colour deficiency in men than in women. The most usual transmission is from maternal grandfather to grandson, through the woman as carrier with one X chromosome affected. A woman will only have colour deficiency if both of her X chromosomes carry similar abnormal genes; hence there is a much lower prevalence of inherited deficiency among females. Brothers of colour-deficient men have a 50% chance of being similarly affected. The different types of red-green colour deficiencies do not occur with the same frequency. Deuteranomalous trichromatism is the most common type.

Table 2: Prevalence of different types of inherited red-green colour deficiency

Type of colour deficiency	Prevalence in men	Prevalence in women
Protanopia	1%	0.01%
Protanomalous trichromatism	1%	0.03%
Deuteranopia	1%	0.01%
Deuteranomalous trichromatism	5%	0.35%
Total	8%	0.40%

6 The gene that specifies the blue photopigment is located on chromosome seven. Colour deficiency derived from abnormalities of this photopigment are inherited as an autosomal dominant trait. An equal number of men and women are affected. The prevalence of inherited tritanopia is estimated to be about 1 in 10 000 and that of tritanomalous trichromatism to be about 1 in 500. People with inherited colour deficiency have normal visual acuity with the exception of monochromats. Inherited colour deficiency affects both eyes equally and does not change with age, but this is not the case for acquired defects.

Characteristics of colour deficiency

7 As colour-deficient people can only see a limited number of colours, their ability to differentiate by colour is restricted. This means mistakes can be made in colour identification and some colours are confused. People with significant colour deficiency (dichromats and severe anomalous trichromats) confuse bright colours in all viewing conditions, whereas people with slight colour deficiency typically confuse pale or dark colours. The range of colour confusions increases in low-level illumination and if the coloured areas are small. Colour confusions for acquired defects are unpredictable and the colour perception of such people is often unstable.

8 The relative luminance (brightness and contrast) of colours is altered in some types of colour deficiency. Protans, especially protanopes, are particularly disadvantaged in practical tasks because reds look dark and may be confused with black. Typical colour confusions in each type of colour deficiency are listed in Table 3.

Table 3: Typical colour confusions in different types of colour deficiency

Colours confused by protans	Colours confused by deutans	Colours confused by tritans
Red/yellow/ yellow-green	Red/yellow/ yellow-green	
Red-purple/ grey/green	Purple/grey/ blue-green	Violet/grey/ yellow-green
Red/black	Green/black	Blue/black
Purple/blue	Purple/blue	Purple/red
Orange/yellow	Orange/yellow	
Red/brown, green/brown	Red/brown, green/brown	
Red/blue and brown/violet, twisted stripes	Red/blue and brown/violet, twisted stripes	Black/white and blue/yellow, twisted stripes

9 Typical examples of difficulties people with red-green colour deficiency have are distinguishing coloured wires, traffic signals, coloured road signs and maps.

10 In general, there is a wide spectrum of severity but protanopes can potentially be the most severely handicapped, followed in rank order by deuteranopes, protanomalous trichromats and deuteranomalous trichromats.

11 Colour deficiency cannot be corrected by wearing coloured spectacles or contact lenses or by any other means. Colour filters can sometimes provide assistance in some occupational settings for a specific task by enhancing brightness differences between colours that are seen as identical by the colour defective.

ACQUIRED DEFECTS

12 The inherited departures from normal colour vision are generally predictable in their characteristics, and affect all parts of the visual field in both eyes. In contrast, there is a wide group of colour vision disturbances which can be acquired during life as a result of ocular or general disease, as a consequence of exposure to a chemical, a wide range of medications or resulting from a physical injury to the head. The incidence of such disturbances is uncertain, although it is estimated 5% of the population have an acquired defect as severe as the 8% with an inherited defect, and in those over 50 years this is probably higher. The general ageing process in itself brings with it subtle insidious changes to vision including colour perception.

13 Acquired colour vision disturbances are a highly-varied group of defects, with frequent departures from established patterns. They can progress, for example, from normal trichromacy to anomalous trichromatism on to a dichromatic stage and even to monochromatism (where most colour vision is lost) or they may be relatively stable. On recovery or withdrawal of the cause, colour vision may typically revert to normal through these phases if the colour loss had been considerable.

Points to be noted are:

- difference in colour perception between eyes. Colour loss may be confined to one eye and/or localised in one part of the visual field;
- colour loss may be accompanied by deficiencies in other visual areas, notably reduced visual acuity, visual field defects, impaired dark adaptation, brightness perception, contrast sensitivity or flicker sensitivity;
- disturbances of blue-green-yellow vision are as common or more common than red-green vision in acquired forms;
- females are affected in the same proportion as males;
- a particularly susceptible population is the elderly because of the increased incidence of oxidative damage (cataract);
- severity of the defect is variable according to the progression of disease or degree of exposure to the drug or chemical;
- transient chromatopsia (appearance of colour on white surfaces/objects) may be present;

- colours can often be named correctly by patients with an acquired defect on the basis of their memory for colours prior to the defect;
- confusion in diagnosis, particularly classification of the defect when clinical tests are applied;
- some acquired defects may imitate inherited defects, so very careful examination is required, as with acquired defects the underlying cause may require treatment;
- any 'unusual' colour vision disturbance or report of a change in colour perception, whether of long-standing origin or of sudden onset, suggests an acquired anomaly.

14 A whole variety of eye diseases can give rise to acquired colour vision defects. These include some very common conditions such as cataract, glaucoma, diabetic complications to eyes, retinitis pigmentosa and age-related macular degeneration. These could be important in the occupational context although the affected person may be unaware of their colour perception change. Systemic diseases such as diabetes, multiple sclerosis and liver conditions may cause profound colour vision losses. A variety of chemicals and drugs affect colour vision indirectly, usually as a consequence of damage to the retina and/or optic nerve; santonin and quinine were among the earliest examples (*Defective colour vision: Fundamentals, diagnosis and management*),² and today there is a growing awareness of the side effects of many medications. Substance abuse, eg cannabis, alcohol or tobacco, can also induce colour vision defects.

Ageing effects

15 Colour vision naturally deteriorates after the age of 40, along with a reduction in visual acuity. The cause is likely to be a reduction in the effectiveness of the cone receptors, but as yellowish pigments build up in the lens of the eye and at the central part of the retina (fovea), this also cuts down the quantity of blue light available for perception. Accordingly, very slight blue defects are seen with advancing age in most people. This can lead to confusion between blues and greens and potentially affect the ability to recognise colour-coded appliances or lights in goods transportation systems.

COLOUR VISION TESTING METHODS

16 When undertaking colour vision testing, the examiner must have received appropriate training in colour vision testing and interpretation of results.

General testing criteria

17 When performing a colour vision test, the examiner **must** ensure that the subject is wearing the vision aids that he/she is normally required to wear, eg clear spectacles or contact lenses. Tinted lenses are not permitted since they alter colour vision. The examiner should also be screened, assessed and classified as having normal colour vision prior to testing others. The correct type and intensity of illumination as specified is essential as it has been shown that colour-defective people can 'pass' clinical tests under differing illumination conditions. The spectral content of the illumination in the test area affects colour appearance and can therefore

alter the effectiveness of colour vision testing. It is vital to ensure that the lighting levels in the test area are adequate. The test area should have either a natural north sky illumination (in the northern hemisphere), or artificial natural daylight fluorescent illumination, ie standard source C lighting. The light source should provide a minimum of 200 lux at the surface of the test for young subjects. However, the City University test (Third edition) recommends a level of about 600 lux for adults and increased values for those over 50. Ideally, the light source should be at an angle of 45° above the plate surface. It should be noted that daylight lamps may only hold the stated level of illumination for approximately six months, after which they deteriorate. **Tungsten lighting is unsuitable.**

18 Test books should be closed when not in use and stored in their box away from direct sunlight.

19 Plates should not be touched by subjects.

20 Records of the test results should be kept and detailed listings of parts of tests which have been failed should be recorded by the examiner.

21 Each eye should be tested separately where an acquired defect is suspected.

The Ishihara plate test

22 The Ishihara plate test consists of either 24 or 38 colour plates. It is the most widely used screening test for red-green deficiency and has been shown to be the most efficient test for this purpose. A very general indication of protan and deutan defects is given in this test, but it is not, as such, a diagnostic test. The test does not screen for blue tritan defects and is unsuitable for testing acquired defects. The 38-plate edition of the test contains five types of design; 25 plates have numerals (Table 1); 13 plates have pathway designs that are intended for use with non-verbal subjects. A test manual is provided, but the examination instructions lack clarity. There is no record sheet and the examiner has to understand the

Table 1: Design and function of the 25-numeral designs in the 38-plate edition of the Ishihara test

Plate	Type of design	Function
1	Introductory	Example plate read correctly by those with normal or colour-deficient vision.
2-9	Transformation	A number is seen by those with normal colour vision and a different number is seen by people with red-green colour deficiency.
10-17	Vanishing	A number is seen by those with normal colour vision but cannot be seen by people with red-green colour deficiency.
18-21	Hidden digit	A number cannot be seen by those with normal colour vision but can be seen by people with red-green colour deficiency.
22-25	Protan/deutan classification	Two numbers are presented on each plate. Protans only see the number on the right and deutans only see the number on the left. Note: If neither number can be seen, protan/deutan classification must be obtained with another test. If both numbers are seen and errors have been made previously, the subject is asked to compare the clarity (or brightness) of the numbers. The subject is classified based on which number appears less clear.

principles of the test. These are not difficult to appreciate if the examiner has normal colour vision. The test is easy to use; special training is not necessary. However, interpretation of results is not always easy if only a few plates are failed.

23 The test plate can be hand held or placed on a table at 'arm's length', approximately 66 cm from the eye. Ideally, daylight illumination or a suitable alternative (see *General testing criteria*) should be at 45° to the plate surface, ie not directly above. The examiner instructs the subject to 'Tell me the numbers that you can see as I turn the pages. Sometimes you will not see a number and then I will turn to the next page'. The examiner turns the pages, keeping control of the viewing time. About four seconds are allowed for each plate. Undue hesitation can be a sign of slight colour deficiency.

24 The Ishihara plates can be purchased readily, and occasionally people try to learn the correct responses in advance of the test. If this is suspected, the plates should be shown in a different order.

Interpretation

25 Most colour-deficient people make 12 or more errors on the 16 transformation and vanishing designs; with 99% of colour deficient identified on a minimum of six errors. This pass/fail criterion is adequate as a screening formula to determine colour deficiency. Some subjects with normal colour vision make one or two interpretative mistakes but errors and misreadings differ qualitatively. The hidden-digit plates only identify about 50% of colour-deficient people and need not be shown. Most dichromats (who make up around 3% of the male population) and all severe anomalous trichromats cannot see numerals on any plate after the introductory design and other tests are then needed to classify the defect for severity and type.

The City University test

26 The City University test (Third edition) is a two-part test, the results of which are recorded on a sheet provided with the test. Part one is a screening aid for detecting defective colour vision and part two identifies the type and severity of the defect.

27 Part one of the test consists of four charts that are used indicate any colour vision defect. This part takes 30 seconds. Each chart has four vertical columns of three coloured spots and the subject must identify the presence and position of any different coloured spot within the column. Part two displays a central colour and four peripheral colours. The subject selects one of the outer colours which 'looks most like the central colour'. This part takes 40 seconds. Protan, deutan and tritan colour deficiency can be classified for both acquired and inherited defects. In part one, normal subjects should detect a total of 9-10 spots correctly on each chart. Deutans and protans should score a total of 4 or 5 missing spots, which are indicated in the instructions. Tritans are likely to score 7 and should, as with deutans and protans, miss the spots indicated in the instructions. In part two, the degree of defect is indicated by the number of errors, with a very mild defect showing few errors and an extreme defect making a maximum number of errors. Part two of the test differentiates based on the error rate between the three main types of colour defect.

Lantern tests

28 Organisations which require the correct recognition of coloured signals (principally transport groups such as the Civil Aviation Authority, railways, maritime, naval and air force) depend upon a standard lantern test which imitates actual signal systems. Their use is confined to the trade task of recognition of coloured lights, principally red, green, yellow and white. Lantern tests require the naming of standardised coloured lights of controlled luminance, colour and size, usually in a dark room.

29 The only lantern test likely to be encountered in the next 20 years is the CAM instrument (clinical, aviation and marine) devised by Fletcher and adopted by the College of Optometrists and the Association of Optometrists to replace the Holmes-Wright (H-W) lantern, which may still be in use but is no longer in production, and the Giles-Archer lantern which is no longer in use or production. The CAM lantern replicates the same specifications of the H-W lantern for colours, intensities and aperture sizes.

30 When performing a lantern test, an examiner needs to ensure that exposure time, size of light stimulus and light intensities are controlled with regular calibration of lamps, filters and apertures using standards. Considerable experience is required in interpreting the results. Lantern tests do not readily allow classification according to type or severity of defect, although dichromats are more likely to mis-name a greater number of lights. The CAM lantern test can be used in both maritime, aviation and land transport situations and a record sheet is provided for automated or manual use. A supplementary computer software package is available allowing automation and standardised recording of results.

SELECTED PROTOCOLS FOR COLOUR VISION

Organisations which use lantern tests:

Army

Classifications of colour perception used are CP1, CP2, CP3 and CP4. Those who make errors on Ishihara plates in daylight fail CP2, and if they recognise signal colours on the approved lantern test (specified as the H-W lantern) are classed as CP3.

Royal Navy

Colour vision classification is the same as for the Army, with the highest standard CP1 requiring the correct recognition of coloured lights shown through the paired apertures of the H-W lantern at **low brightness** at six metres in complete darkness. Candidates may wear glasses and be dark adapted if necessary.

Royal Air Force

The classification system used is as for the Army. Different trades require appropriate classification.

Civil Aviation Authority

Two classes: Joint Aviation Requirement (JAR) Class 1 and Class 2. Candidates must make no errors on the Ishihara. Those who fail Ishihara are assessed as colour safe if they pass extensive tests with 'acceptable methods' such as the H-W lantern or anomaloscope. These standards are applicable to air-traffic control officers, flight engineers, flight navigators and commercial balloon pilots. Microlight pilots must have 'colour vision assessed'.

Seafarers and coastguard

Those who fail (Ishihara, Farnsworth D-15 or City University testing) may arrange to be tested using the H-W B lantern (the CAM lantern provides this alternative standard as well as the A standard).

Lifeboat crew (RNLI)

If Ishihara plates are failed, or in cases of dispute or uncertainty, candidates may be asked to undertake a lantern test.

Trade tests

Colour naming is usually avoided in a colour vision examination. A person has to distinguish a figure in a carefully constructed pseudoisochromatic design, arrange colours in sequence or match colours together. Asking a candidate to name a few coloured wires or the bands on resistors or capacitors does not constitute an adequate colour vision test, either for screening or identifying severe colour deficiency. On the other hand, a practical test using components or manufactured items, viewed in the existing lighting conditions, may assist borderline decisions in assessing the capabilities of an employee to perform the task in question. However, it is always desirable to formalise the test to make sure that the results can be justified and that the same test can be repeated by another examiner.

THE AVAILABILITY OF COLOUR VISION TESTS

Test	Function	Supplier
The Ishihara plates	Screening for red-green colour deficiency.	<p>Any medical bookshop or bookshop with a medical department.</p> <p>Keeler Ltd, Clewer Hill Road, Windsor, Berks SL4 4AA Phone: 01753 857177 Fax: 01753 857817 email: info@keeler.co.uk</p> <p>Clement Clarke International Ltd, Edinburgh Way, Harlow, Essex CM20 2TT Phone: 01279 414969 Fax: 01279 456304 email: info@clement-clarke.com</p>
The City University test (Second and third editions)	Grading the severity of red-green colour deficiency. Possible grading of protan and deutan defects if the test is failed. Identifying tritan defects.	<p>Keeler Ltd, Clewer Hill Road, Windsor, Berks SL4 4AA Phone: 01753 857177 Fax: 01753 857817 email: info@keeler.co.uk</p> <p>Clement Clarke International Ltd, Edinburgh Way, Harlow, Essex CM20 2TT Phone: 01279 414969 Fax: 01279 456304 email: info@clement-clarke.com</p>
CAM Lantern	Determining the ability to recognise standardised coloured lights of varying size and intensity	<p>Evans (Instruments) Ltd, 35 Howlett Way, Thetford, Norfolk, IP24 1HZ Phone: 01842 766004 Fax: 01842 754597 email: sales@evansinstruments.co.uk</p>

REFERENCES AND FURTHER READING

References

1 *Colour vision examination: A guide for employers*
Information sheet WEB03 HSE 2005 Web-only version
available at: www.hse.gov.uk/pubns/WEB03.pdf

2 Fletcher R and Voke J *Defective colour vision: Fundamentals, diagnosis and management* Institute of Physics 1985 ISBN 0 85 274395 5

Further reading

A practical guide: Employment adjustments for people with sight problems Employers Forum on Disability 2000

Cox R A *Fitness for work: The medical aspects* (Third edition) Oxford University Press 2000 ISBN 0192630431

Successful health and safety management HSG65 (Second edition) HSE Books 1997 ISBN 0 7176 1276 7

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FURTHER INFORMATION

HSE produces a wide range of documents. Some are available as printed publications, both priced and free, and others are only accessible via the HSE website, www.hse.gov.uk.

HSE priced and free publications are available by mail order from HSE Books, PO Box 1999, Sudbury, Suffolk CO10 2WA Tel: 01787 881165 Fax: 01787 313995 Website: www.hsebooks.co.uk (HSE priced publications are also available from bookshops and free leaflets can be downloaded from HSE's website: www.hse.gov.uk.)

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This document contains notes on good practice which are not compulsory but which you may find helpful in considering what you need to do.

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www.hse.gov.uk/pubns/ms7.pdf

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