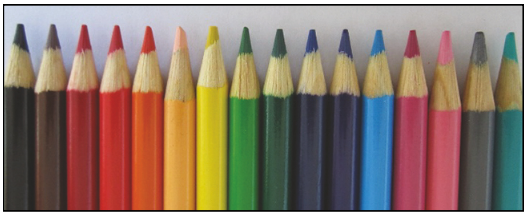
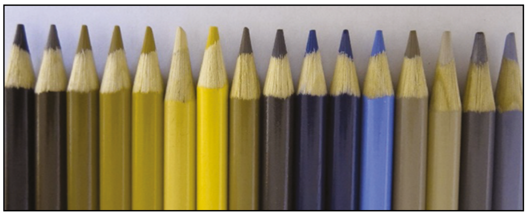
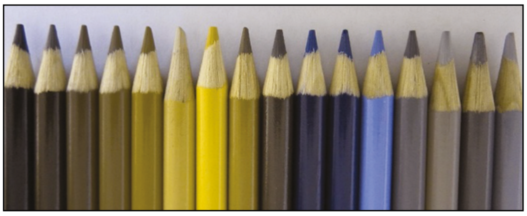
How to design accessible and inclusive assessment materials for colour blind learners



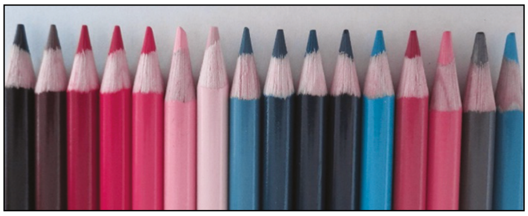
Normal colour vision



Severe green deficiency (deuteranopia)



Severe red deficiency (protanopia)



Severe blue/yellow deficiency (tritanopia)

wjec cbac

COLOUR BLIND AWARENESS

NOVEMBER 2020

"As a colour blind teacher, I see HUGE gaps in knowledge and understanding about how CVD can impact learning. Often when I've been able to spend time explaining to staff, they empathise and understanding develops. Definitely more awareness is needed in schools."

Chris Tully – Achievement Director

"It's so easy when you can see colour to take it for granted. Through the various simulations we can run, it's clear that not everyone has the same access and we find ways to neutralise this disadvantage."

Gareth Roberts – Senior Graphic Artist, Assessment Materials Unit, WJEC

"A lot of my coursework relied on colours for graphs, which I found difficult and I'd be worried about exam papers with coloured sections. When exam papers are black and white I don't have problems understanding information. My current maths teacher uses information in PowerPoint where the background and the text are too similar, so I have to rely on my friends to tell me what they say. My teacher has been unwilling to help when I've asked but I think this is probably because he doesn't understand."

Josh I, student aged 18

Contents

PART 1

Introduction

This Guidance has been commissioned by WJEC in collaboration with Colour Blind Awareness. It is for those who are involved in the design of examinations and written assessments and concerns the accessibility and inclusivity of these assessments for colour blind learners. The Guidance uses practical examples and simulations to demonstrate the challenges experienced by colour blind candidates, when faced with colour in an examination paper, and the importance of avoiding common pitfalls and assumptions about colour. By applying the basic principles and best practice design techniques outlined in this Guidance, we can ensure that assessments are fair to all learners and no candidate is disadvantaged or potentially excluded from any element because of the use of colour.

The Checklist included at the end of this Guidance draws together the main principles and can be used when planning the design of your examinations and written assessments.

What is colour blindness?

Colour vision deficiency (CVD), more commonly known as colour blindness, is one of the world's most common inherited conditions and affects 1 in 12 boys (8%) and 1 in 200 girls (0.5%). Statistically speaking, at least one child in every (co-ed, maintained) classroom will have some degree of colour blindness.

In the UK there are approximately 450,000 colour blind school age pupils (19,500 colour blind pupils in Wales) but due to a combination of factors, including:

- the removal of school entry colour vision screening;
- no legal obligation placed on optometrists to include colour vision screening within the NHS eye test for children;
- lack of awareness of parents; and
- no formal training for teachers

most colour blind learners remain undiagnosed throughout their entire school career. Many colour blind learners are unaware of their condition well into adulthood and can, therefore, also be disadvantaged as mature students.

In a statistical context, in 2019 approximately 233,000 of the 5.18 million Summer entry GCSE papers sat in England would have been attempted by candidates with a colour vision deficiency. In terms of Geography alone, approximately 11,400 colour blind candidates would have sat the Summer GCSE papers in England. Therefore, it is extremely important that examination papers are designed to accommodate the needs of these learners, many of whom will be unaware that they have the condition.

As the majority of colour blind learners are undiagnosed, they are unable to benefit from Access Arrangements. For this reason, exams and written assessments must be inclusive from the outset.

Causes of colour blindness

Humans see colour through three different types of nerve cells called cones, which are located in the retina at the back of the eye. These three cone types absorb red, green and blue light respectively and send signals, in the form of electrical pulses, to the brain. The brain then interprets this information to allow people with normal colour vision to experience millions of different colours.

In genetic colour blindness, one cone type doesn't function correctly, resulting in confusion because many different colours can appear similar. Approximately 25% of colour blind people, known as dichromats, are completely missing one cone type.

CVD can also be acquired, most commonly either as a side effect of some diseases, including diabetes and multiple sclerosis, or from some drugs and medications. While acquired conditions can sometimes improve, inherited colour blindness has no cure.

Types of colour blindness

The most common types of inherited CVD affect either the red or green cones and are often mistakenly referred to together as 'red/green' colour blindness. Although there are many similarities in the way colours are experienced by people with both red (protanopia) and green (deuteranopia) deficiencies, there are some important distinctions – not least that people with red deficiencies often mistake reds and browns for black.

Blue/yellow vision loss (tritanopia) can be inherited and is extremely rare, although blue/yellow vision loss is not uncommon in acquired colour blindness.

Monochromatic (greyscale) vision is also extremely rare but is a characteristic of some other eye conditions, most commonly achromatopsia (see References).

Red/green types of colour blindness are usually diagnosed using the Ishihara test. This is a simple, inexpensive screening test, which can be undertaken from school entry (age 5+). Blue/yellow colour blindness cannot be detected by the Ishihara test and requires specialist testing using the City University test or more sophisticated testing under university laboratory conditions.

Whichever type or severity of colour blindness a person may have, they may confuse many different colour combinations, not just reds and greens. The commonly held view that colour blind people only confuse red and green is simply a myth.

For more information on the different types and severities of colour blindness, refer to http://www.colourblindawareness.org/colour-blindness/types-of-colour-blindness/.

Legal framework

There is often confusion amongst educational professionals over whether colour blindness can be considered a disability. This is mainly due to lack of knowledge of the condition, but the Equality Act 2010 states:

A person has a disability for the purposes of the Act if he or she has a physical or mental impairment and the impairment has a substantial and long-term adverse effect on his or her ability to carry out normal day-to-day activities.

Whether a learner is disabled in the context of access to an examination paper depends on whether they can distinguish all of the information in the assessment and its associated resources **to the same extent** as other candidates without the condition. If, for example, all the information within the paper and associated resources is provided in greyscale to all candidates, then a candidate with CVD would not be at a disadvantage. If, however, some information (e.g. a line graph) is provided to all candidates in colour with a colour-only key, candidates with CVD are likely to be disabled from answering the questions when compared to candidates with normal colour vision.

What's more, the legal implications of not adequately accounting for the needs of candidates with CVD are also more wide-ranging than for most other disabilities. Males are 16 times more likely to be colour blind than females; so failure to account for colour blind candidates in examinations can lead to claims of indirect sexual discrimination.

What concerns colour blind candidates?

Whenever a colour blind candidate is faced with information presented in colour in an exam, an element of anxiety is likely to be introduced. Commonly, candidates with CVD will subconsciously try to make sense of information in colour before they read a question in detail. This means where accurate colour identification is **not** integral to answering the question, these candidates can waste valuable time. In simple terms, unless it is expressly stated that colour has no meaning, candidates are likely to try to make sense of the different colours before answering a question.

By contrast, a candidate with normal colour vision is instinctively and automatically able to understand different colours. So even where we make information in colour accessible to candidates with CVD, they remain at a disadvantage because it will take them more time to work out the different textures/symbols, etc. and their relevance. The more complicated the hatching, the more time will be spent in deciphering information. In the meantime, candidates with normal colour vision can press on.

There will also be increased demands on the working memory of CVD candidates when compared to others. For example, when matching a coloured and hatched key with the corresponding elements of a map.

We must aim to remove these barriers by designing accessible information that can be understood equally easily by all candidates, whether they are colour blind or not. This will allow candidates with CVD to approach exam situations in full confidence that they will not be potentially excluded from some elements of the assessment.

We must also consider how questions are framed and bear in mind that many concepts are based on an intuitive knowledge of colour and that these concepts may have been lost on colour blind learners for their whole lives (for example, a question based around camouflage or a question asking for a descriptive piece of the effect of oil upon water).

Similarly, there are conventional wisdoms applied to many diagrams that may have passed CVD candidates by. For example, the conventional wisdom for complicated pie charts is to match the key to the segments by working from top to bottom of the key to match the segments in a clockwise direction – starting at 12 o'clock. People with CVD (and most school children) are highly unlikely to be aware of this convention. Even those with CVD who may be aware will be wary of relying upon it because conventions aren't always followed, especially if the key is split into two rows where space is tight (see Figures 7a and 7b).

The very fact that candidates with CVD might be unsure about how to interpret colour-only keys in an exam will put them at a disadvantage due to:

- the time they waste in trying to understand it; and
- the impact on their confidence.

We must ensure that questions make it clear where colour is incidental. But if it **is** only incidental, we must ask ourselves why it is being used in the assessment in the first place.

Common design features in an assessment that can disadvantage colour blind candidates

The following is a list of common design features in an assessment that can disadvantage colour blind candidates and should be avoided:

- Coloured bar charts, line graphs, choropleth maps, etc. with colour-only keys
- Pie charts – unseparated segments, unlabelled segments, colour-only keys
- Maps and plans with colour-only keys
- Lack of colour contrast between background colour and labels, for example whether this is text, symbols, hatching, textures – refer to Figures 10a and 10b as examples of good practice
- Text highlighted in different colours to indicate different meanings
- 'Invisible' information on photographs and diagrams, for example a red line to indicate the boundary of a parcel of land on an aerial photograph – refer to Figures 13a and 13b

Part 2 of this Guidance will demonstrate the simple and practical steps we can take, and the considerations we must bear in mind, to ensure that we are producing fair, accessible and inclusive assessments for all colour blind learners.

PART 2

How to design question papers that are accessible to CVD candidates – a practical guide

Before you start

Before you start to plan the content of exams or written assessments, there are a few important points to bear in mind.

Fair Access by Design states:

[Qualifications should be designed to give] all learners the fairest possible opportunities to show what they know, understand and can do.

An accessible and fair assessment will not include any irrelevant features that could prevent certain groups of learners from fully demonstrating what they know, understand and can do. In many instances, colour can be considered an irrelevant feature that could prevent some learners (candidates with CVD) from fully accessing aspects of the assessment. These candidates can be at a distinct disadvantage when compared with candidates with normal colour vision.

When considering whether the use of colour is justified in an exam paper, firstly we must think about what the assessment is measuring (the assessment construct). From there, we can then ask ourselves three important questions:

1. Is the use of colour **integral** for measuring the assessment construct?

2. Might the use of colour be **useful** for measuring the assessment construct but not strictly necessary?

3. Is the use of the colour merely **incidental**? I.e. it doesn't help to measure the construct and is there for decorative purposes only.

Candidates must not be expected to differentiate between colours unless it is **integral** to the assessment construct (e.g. distinguishing between the colours of different bands on electrical resistors).

Whilst the use of colour can be considered integral and useful for measuring the assessment construct for some questions, and is therefore justified, **the use of incidental colour in an examination paper should normally be avoided**.

Keep it simple!

- Most of the measures that ensure assessments are inclusive for colour blind candidates are relatively simple, straightforward and common-sense actions.
- There is no need to find different solutions for each type or severity – the same measures can be equally applied for all types and severities of colour blindness.
- Different types of information can be identified by changing font size, using bold, underlining, using different font types, etc. But it is important to ensure that these techniques do not create issues for other types of learner (e.g. those with dyslexia).
- People with CVD perceive contrast differently to people with normal colour vision. This means that in some situations, pale text (including grey text) can be invisible to people with CVD against a white background, even though it is legible to someone with normal colour vision. In the case of maps, areas identified in white can be confused with areas shaded in pale grey and pastel colours.
- People with colour blindness cannot be expected to know if they have missed information given in colour only. People with colour blindness often believe, incorrectly, that they have understood all the information in a photograph or diagram. Therefore, colour blind people should not be asked to test designs for accessibility (unless they have received CVD accessibility training).
- There is no such thing as range of colours forming a 'safe colour palette' that can be applied to any maps/charts, etc.
- Pastel colours can all appear 'grey' to people with CVD and should always be avoided in examination papers – refer to Figure 5.
- Red should never be used as a contrast to black (because people lacking red cones perceive many reds as black).
- Not all reds are confused with all greens. Some combinations of red and green are easy to tell apart if they exceed minimum colour contrast ratio recommendations, for example lime green and dark red (see pages 17 to 19 and the Appendix for guidance on colour contrast ratio).
- Unless minimum colour contrast ratios can be achieved between ALL the colours on a diagram that convey information, the information MUST be given by alternative means, for example text/symbols/numbers.
- Minimum colour contrast ratios must be achieved between text/labels/textures, etc. and background colours (including the colour of the paper). For example, yellow text would not be accessible on white paper.
- Wherever possible, it is recommended that minimum colour contrast ratios are exceeded because:
    (i) for digital information, different computer settings can result in different colour contrast ratios for the user than those that were originally envisaged by the designer; and
    (ii) where information is designed digitally (specified in RGB, Hex, etc.) but will also be printed (specified in CMYK), a degree of error can occur, which can result in reduced contrast in the printed version.

The Graphics Team will assess all resources against the criteria set out in the Checklist before they are approved for proofing.

Many colours appear similar to learners with CVD

People with CVD may be able to correctly identify many different colours, but this does not mean they see the colours in the same way as people with normal colour vision. Using unconscious coping strategies, people with CVD can appear to be reliable at 'identifying' colours correctly based solely upon previous learnt experience of the likelihood of the shade of colour they perceive being a certain colour.

In situations where many colours are involved, several different colours are likely to appear similar to candidates with CVD, for example on an atlas with a colour-only key (see Figures 1a and 1b). In this type of situation, coping strategies break down because too many adjacent colours appear similar. By contrast, people with normal colour vision can instinctively identify many different colours automatically.

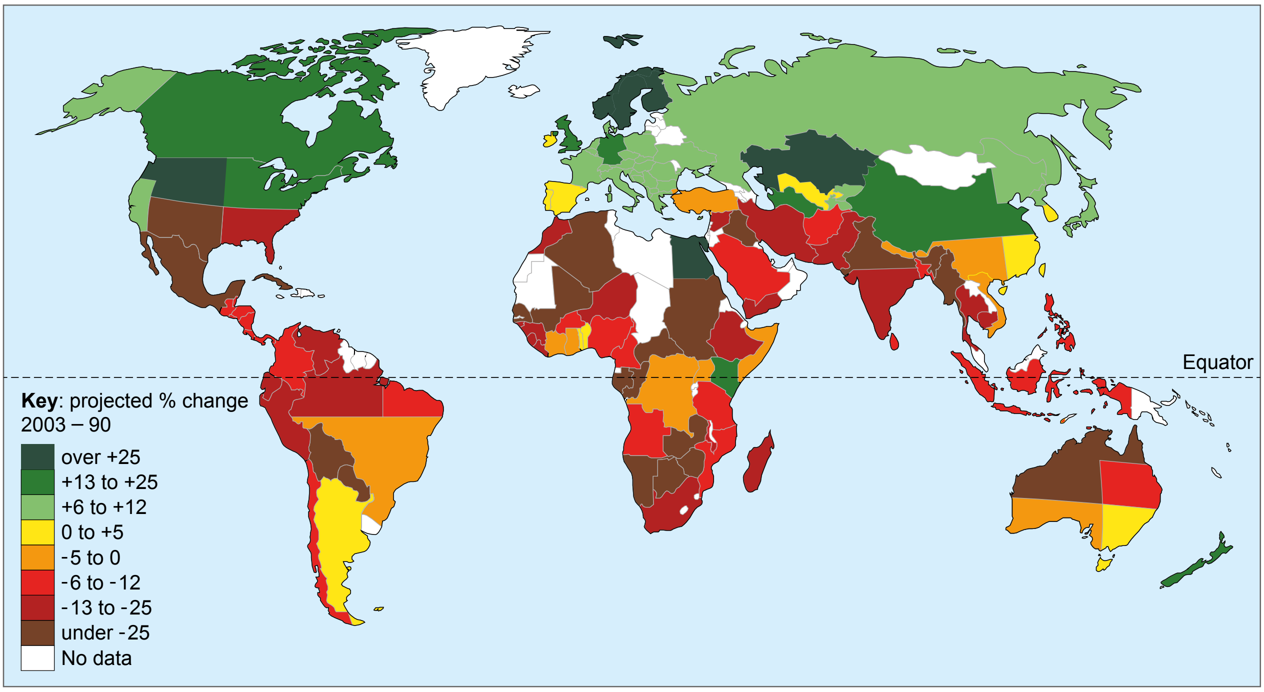


Figure 1a – normal colour vision – poor practice

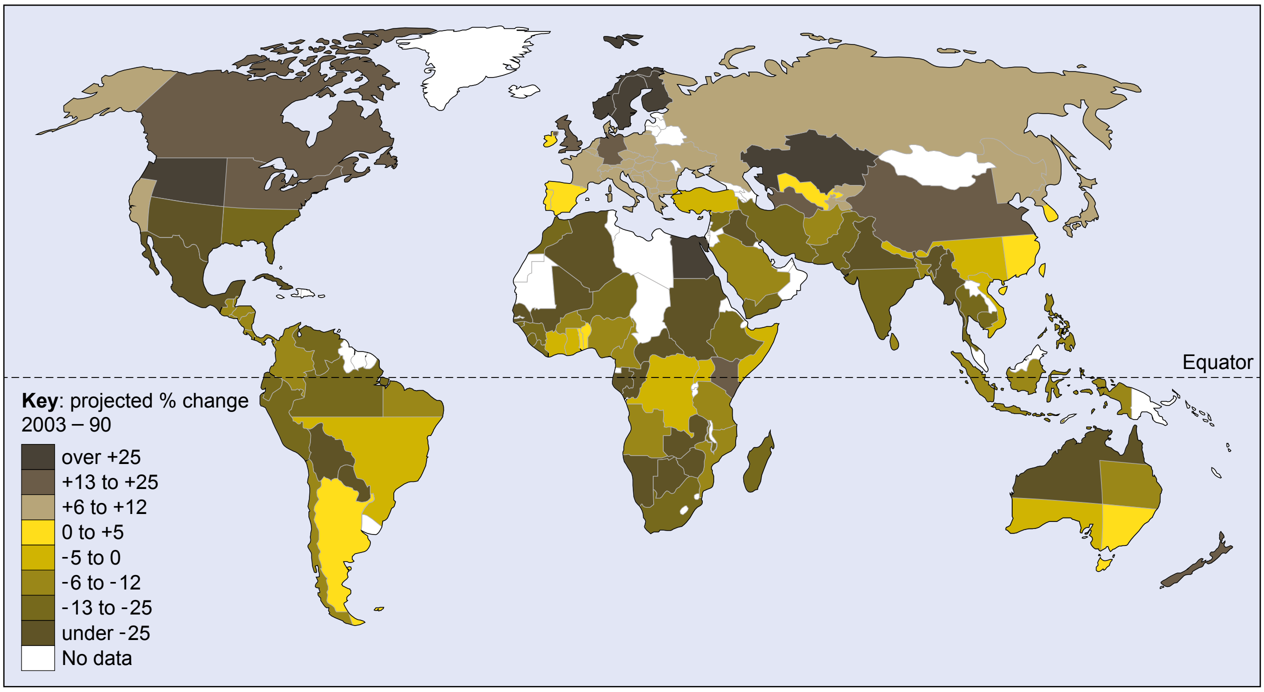


Figure 1b – 'colour blind' simulation of Figure 1a

It is easy to understand when looking at Figures 1a and 1b, and 2a and 2b at page 13 that a colour blind candidate would be at an immediate disadvantage in an exam situation compared with a candidate with normal colour vision. This would be the case even if the colour blind candidate was diagnosed and therefore able to request Access Arrangements (such as asking the invigilator to name the colours for them). This is because the colour blind candidate would be unable to retain the colour information provided by the invigilator unless it was also marked onto their resource. To do so would result in lost time and disturbance to other candidates. This would also require the candidate to correctly mark up their own resource (since marking up by the Exams Officer in advance would not be permitted as it would be considered to be tampering). There should never be any need for a candidate to have to mark up their own resources in an exam situation. If more than one CVD candidate is sitting the paper, then they may even have to wait for the invigilator's attention. This is not a satisfactory solution.

Designing question papers that require supporting diagrams

When designing for colour blindness always start with this basic rule in mind – **NEVER CONVEY INFORMATION BY COLOUR ALONE**.

The best practice starting point is to consider whether colour is **essential** to the assessment in order to assess the extent of the candidates' knowledge. Does adding colour really provide additional, necessary information that cannot be provided by other means or is it only proposed to add visual interest?

A rationale should be provided to justify the use of colour, which should also consider the cost implications such as more expensive printing and the added work required to meet online accessibility requirements at the point at which the information is published online.

To truly understand whether colour is needed, start by designing any accompanying diagrams in black and white. If more differentiation is needed, add information in text and then consider adding texture (e.g. hatching, dotting, symbols).

Tips for accessible keys

It might seem obvious, but it is quite common for textures to be added to distinguish between colours of maps and charts without remembering to add the hatching to the key. Therefore, be sure to:

- match information on the chart to its key;
- check the textures/patterns/symbols are legible in the key as well as on the chart;
- enlarge the key blocks if necessary (see Figures 2c, and 6a and 6b as examples of poor practice. Figure 2d demonstrates good practice); and
- check colour contrast ratios between textures and the colour of the chart/key.

There is usually no need to hatch every element of a diagram as too many patterns can be confusing to everyone and take extra time to distinguish between, even at large scale. Therefore, it is important to also consider the ease of distinguishing between different elements of a diagram.

Consider Figures 2a and 2b. Figure 2a is the standard coloured inset. Figure 2b is the colour blind simulation of Figure 2a. Figure 2c is a monochrome equivalent, which employs commonly used techniques to convey the same information.

Comparing Figures 2a and 2b reveals the need for a suitable solution for colour blind candidates.

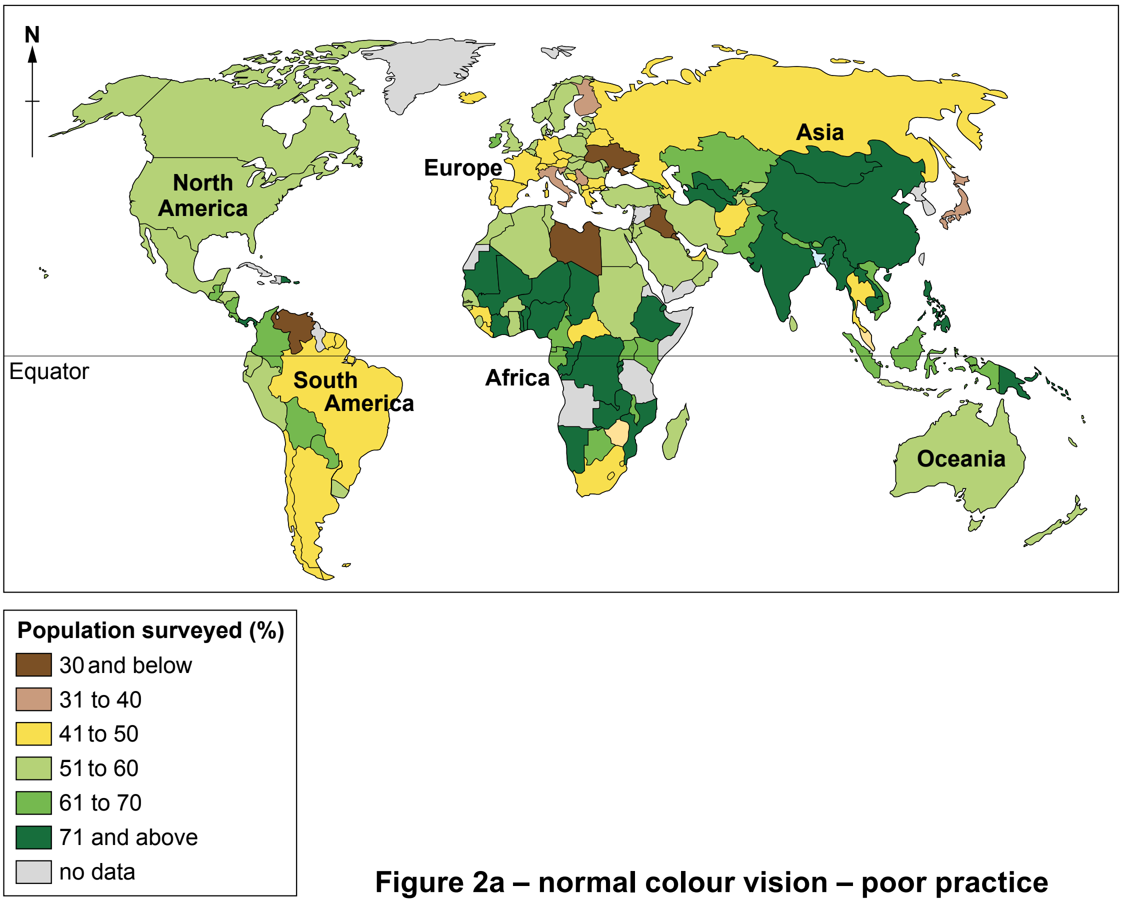


Figure 2a – normal colour vision – poor practice

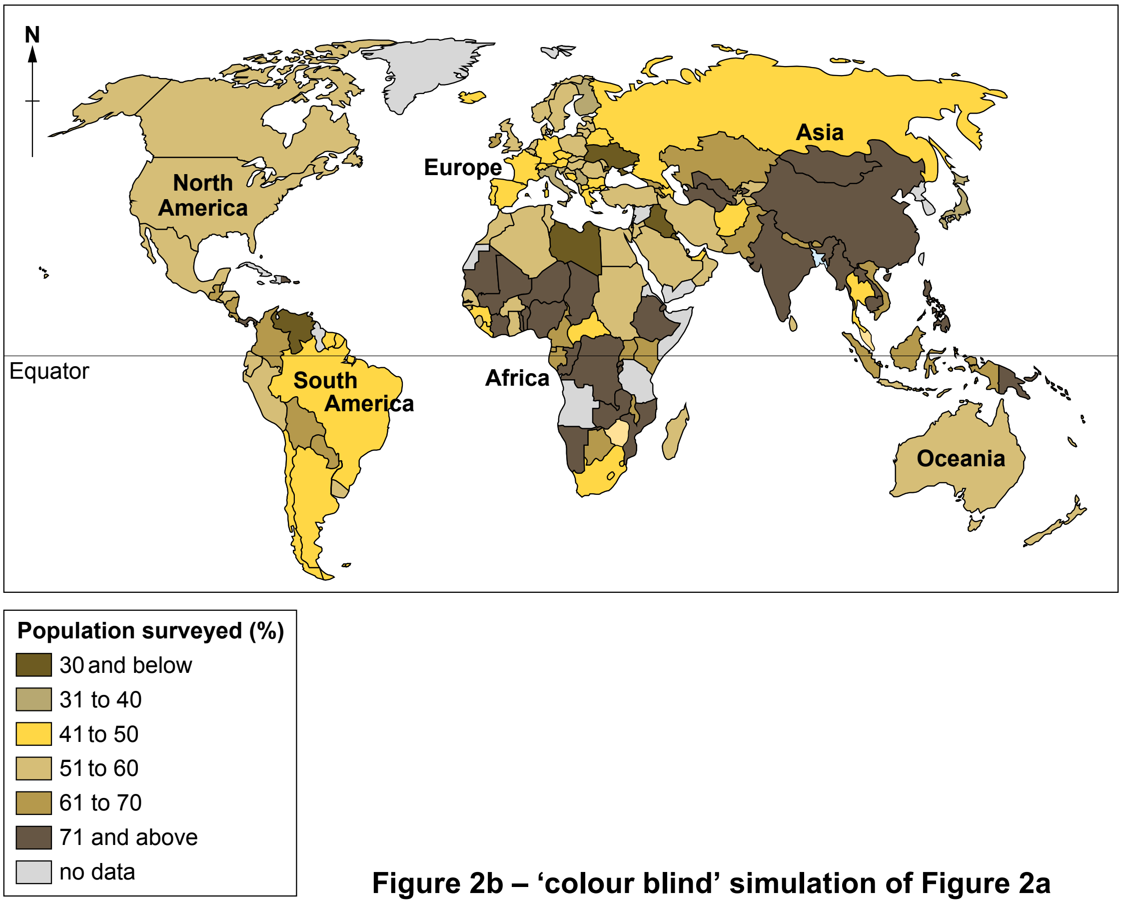


Figure 2b – 'colour blind' simulation of Figure 2a

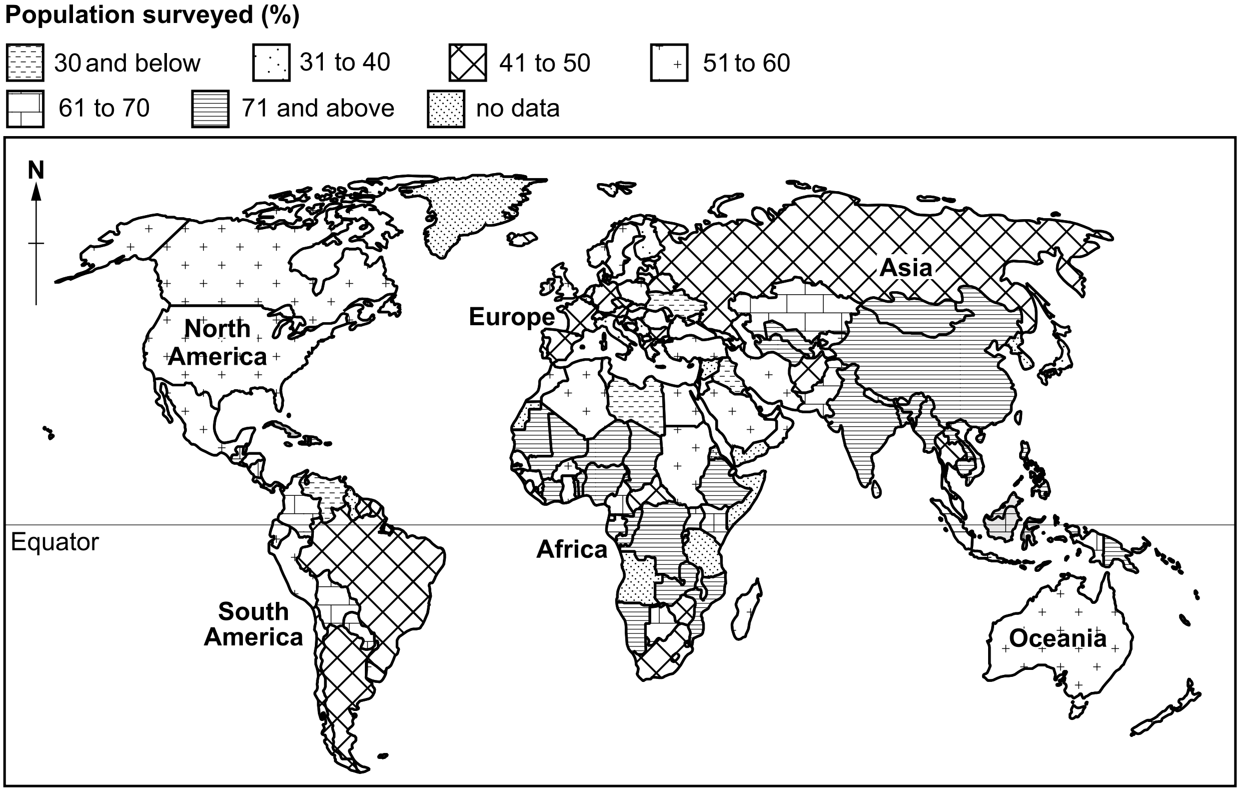


Figure 2c – potential monochrome solution for colour blind candidates – poor practice

Consider Figures 2c and 2d. Figure 2c is an example of a poor practice ‘solution’. It is too complicated as a potential solution and places CVD candidates at a disadvantage due to the time needed to properly interpret the information. The information in Figure 2c could have been conveyed much more easily by using a combination of different shades and types of pattern. See the good practice example Figure 2d where the increased size of the key boxes also means the patterns are easily distinguishable.

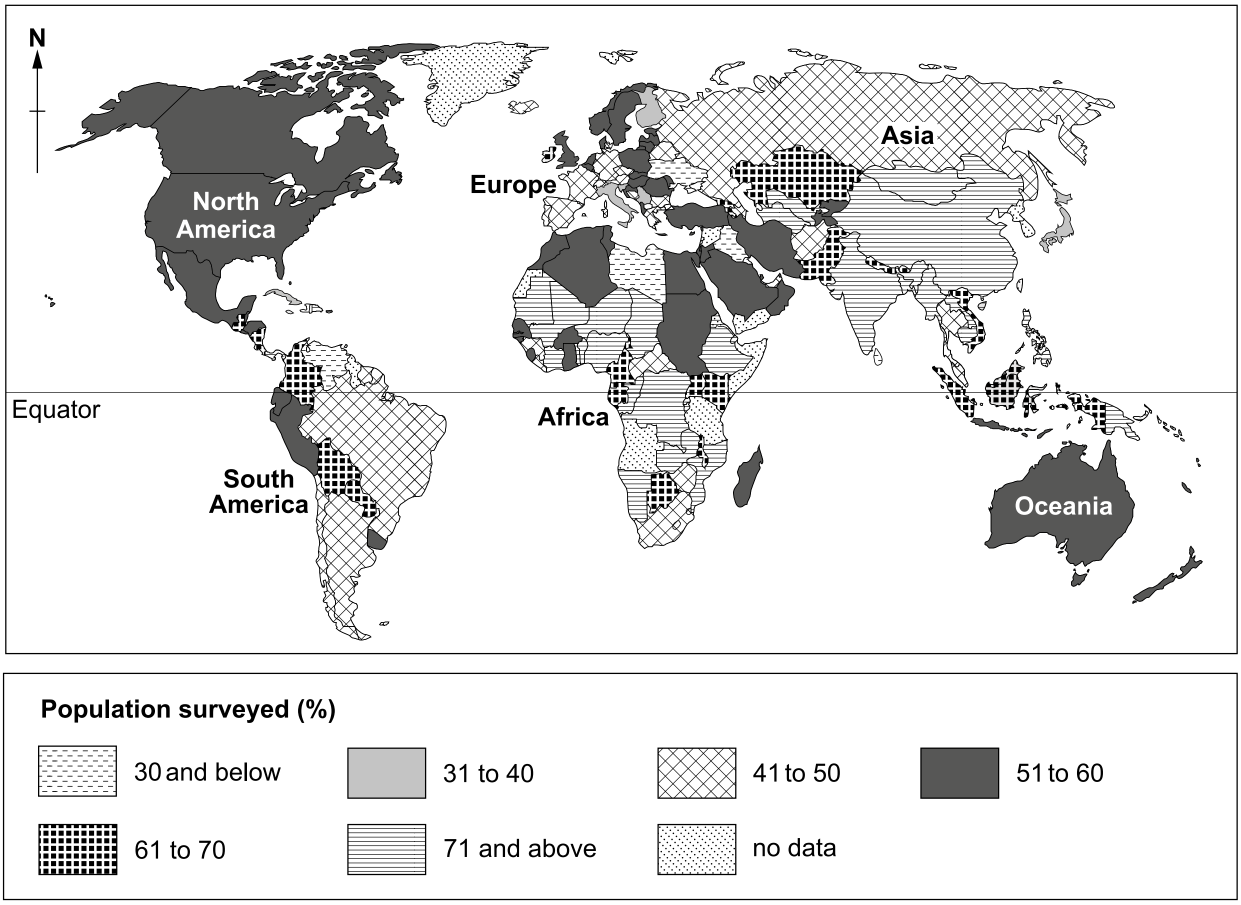


Figure 2d – potential monochrome solution for colour blind candidates – good practice

If an element of colour is essential, for example for a complicated diagram where too many patterns would add confusion, colour can be used, provided information is not conveyed by colour alone. Minimum colour contrast ratios must also be met (see Appendix). Therefore, before adding colour, consider whether such a complicated diagram is really suitable for the question or whether a simpler version might be better.

Figures 1a and 1b, and 2a and 2b demonstrate that using colour alone can be confusing for colour blind candidates due to the difficulties they have in retaining colour information when moving from the coloured key to the map.

Figure 3a, however, demonstrates good practice as it combines colours and patterns to ensure information can easily be matched from the key to the map.

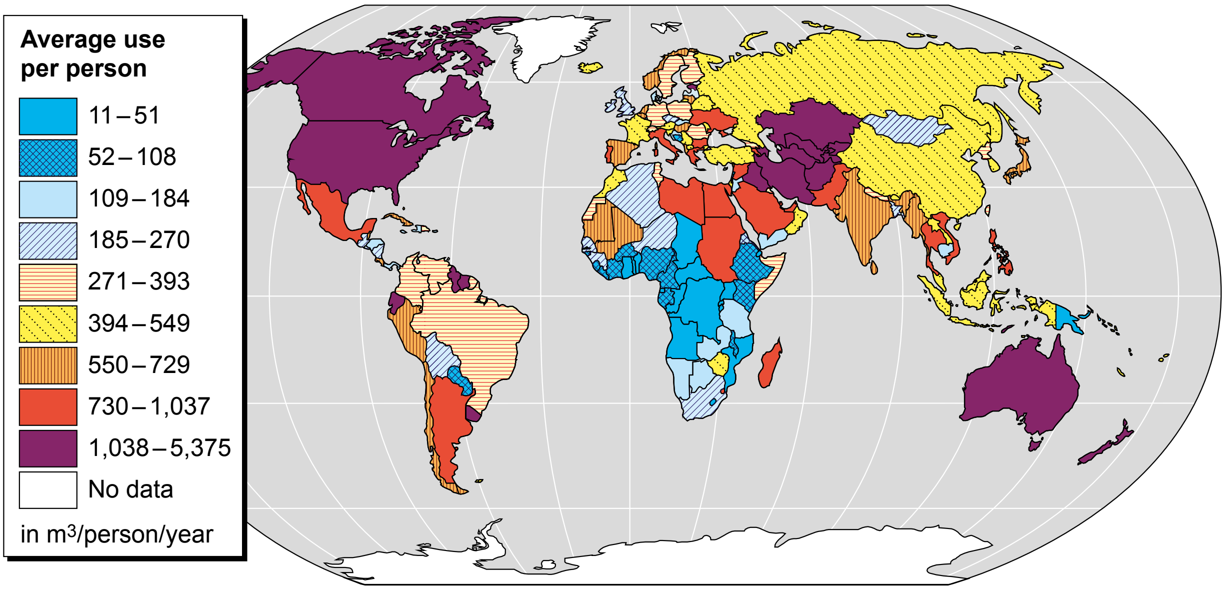


Figure 3a – normal colour vision – good practice

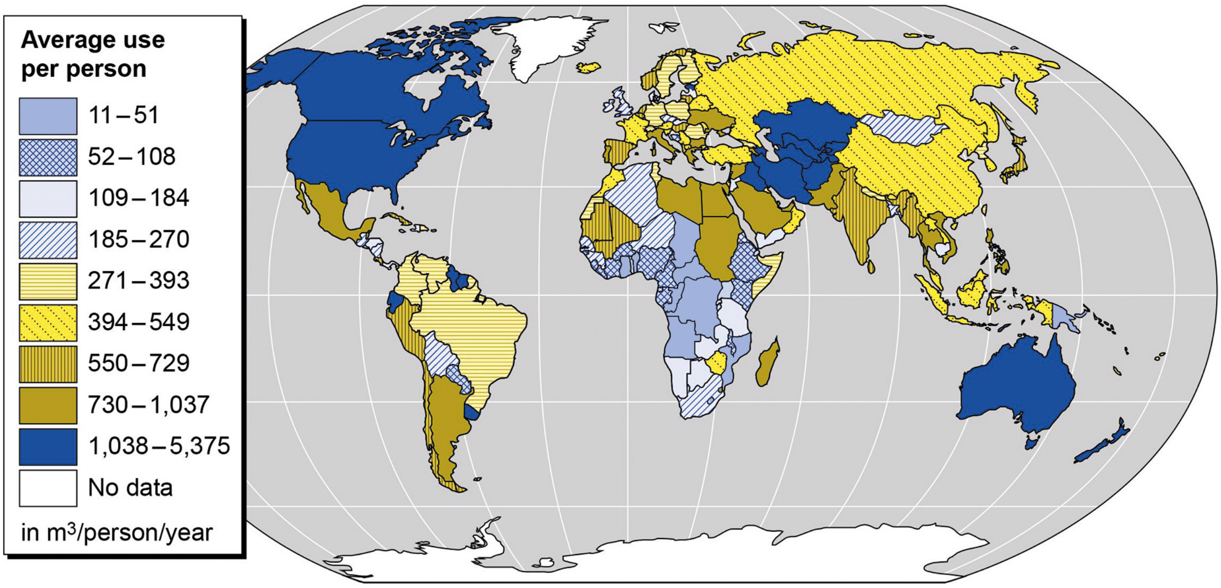


Figure 3b – 'colour blind' simulation of Figure 3a

List of common design pitfalls

The following is a list of common design pitfalls:

- assuming colours have strong colour contrast without checking using software
- relying upon conventional wisdom being seen and understood by everyone, for example red means bad/danger whilst green means good/safe
- using pastel colours for comparisons
- relying on a colour blind colleague or student to advise if information is accessible (they can only advise for their own type/severity and may not be aware if they have missed any information)
- assuming boundaries between different colours are obvious just because the colours are different (refer to Figure 5 and imagine no white boundaries between different coloured segments)
- assuming text/symbols against background colours can be read by everyone
- using red/amber/green to indicate a different status level, for example a traffic light rating system
- using red as a contrast to black

Colour contrast ratio

For it to be accessible for candidates with CVD, information given in colour only **MUST** meet minimum standards of colour contrast known as minimum colour contrast ratios. Ideally, minimum colour contrast ratios should be exceeded.

> Please note that Appointees are not expected to check or ensure minimum colour contrast ratios have been met – this will be done by the Graphics Team in the Assessment Materials Unit.
>
> But the information that follows is useful to help understand why the use of colour might look different to that which was originally submitted for typesetting.
>
> More information on minimum colour contrast ratios and how to check this using the appropriate software can be found in the Appendix.

A common mistake made by people with normal colour vision is to think that because two colours have strong contrast for them, they must have strong contrast for everyone. See the example at Figures 4a and 4b. Here, someone with normal colour vision may consider that there is strong contrast in 4a; but in the colour blind simulation 4b there is virtually no contrast.

Figure 4a – normal colour vision

Figure 4b – 'colour blind' simulation of Figure 4a

The minimum colour contrast ratio needed to ensure accessibility for people with CVD is 3:1 (assuming large text, AA rating) but the colour contrast ratio between the 'red' and 'green' in Figure 4a is only 1.8:1. The implications for learners with CVD of vital information not achieving the minimum recommended colour contrast ratio are shown in Figure 4b. This demonstrates the importance of checking colour contrast ratios using software, since it would be easy for people with normal colour vision to make mistakes otherwise (see Figure 5).

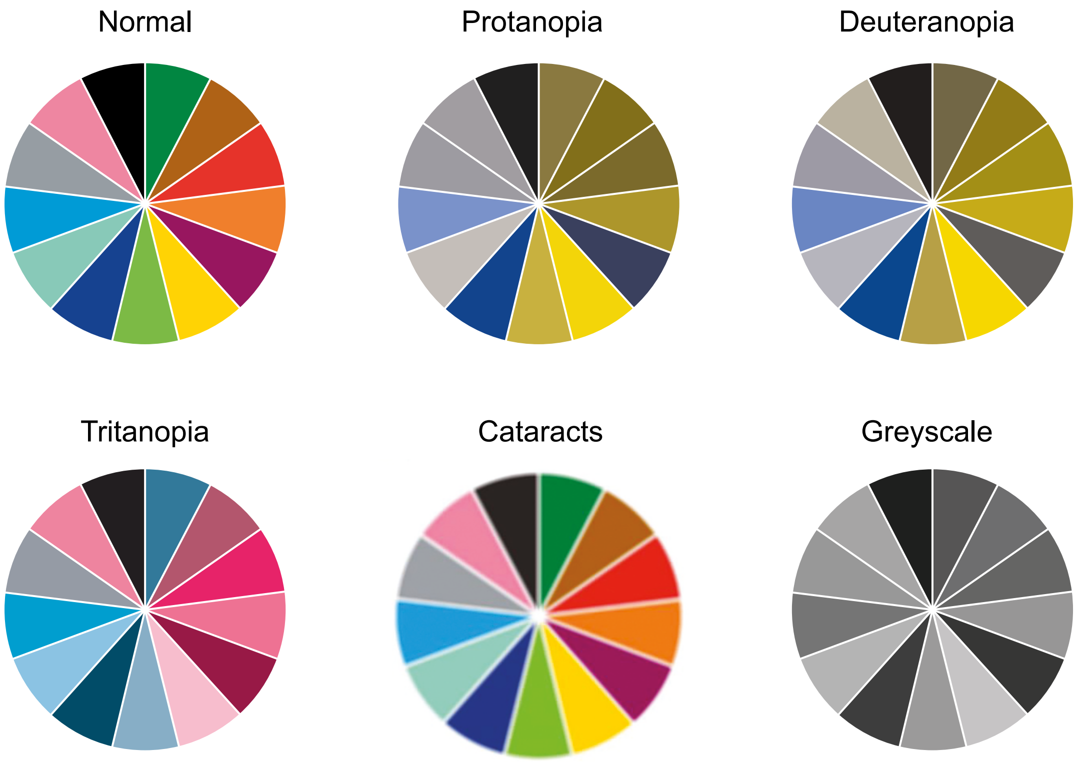


Figure 5 – Examples of software that compares simulations of original 'normal' images for different types of vision impairment

As so many different colours can appear similar to people with colour blindness, it is unlikely that more than three or four colours can be found for use in a single diagram that all meet minimum colour contrast ratios (AA rating) when compared with each other.

Some designers advocate that sufficient contrast can be created by using combinations of:

(i) cool and warm colours;
(ii) contrasting colour saturation; and
(iii) complementary contrast

but none of these techniques reliably ensures accessibility for candidates with CVD and should be avoided.

Minimum colour contrast ratios

The only reliable solution for colour blindness accessibility is to use software tools (see References) to check whether minimum colour contrast ratios have been achieved.

For information on how to apply and check minimum colour contrast ratios, refer to the Appendix.

What to do when minimum colour contrast ratios can't be achieved

If the use of colour is essential, and to avoid hours of frustration trying to find a set of colours that meet the minimum contrast ratios, it is much easier to fall back on some simple, common sense techniques to allow the information to be distinguished.

The simulations of the three main types of severe colour blindness at Figure 5 demonstrate the difficulties in finding a colour scheme that is accessible for all types of CVD. However, using one or more of the techniques shown using the pie chart in Figure 6a as an example can ensure information is accessible without removing the colours.

Remember:

- keep designs as simple as possible;
- it shouldn't be necessary to use all techniques at once; and
- you will need to consider the amount of space available, font size, general legibility, etc. to decide which techniques are best suited to your pie chart or other diagrams.

Good practice techniques for pie charts

Figures 6a and 6b demonstrate how using effective labelling techniques can be the difference between colour blind learners being able to make sense of information in simple charts and diagrams or not.

- **Maximising contrast ratios between each coloured segment**
  - alternative – use different textures to distinguish between some segments, matching to the key (refer to 'Tips for accessible labelling' at pages 28 to 29)
- **Separating each segment with a highly contrasting colour**
  - alternative 1 – 'explode' the segments, ensuring minimum colour contrast ratios are achieved between each segment colour and the background colour (of the paper)
  - alternative 2 – where space is tight, change the design to a doughnut, which allows some information to be added via labels/arrows within the 'hole' and further information via arrows outside the doughnut segments

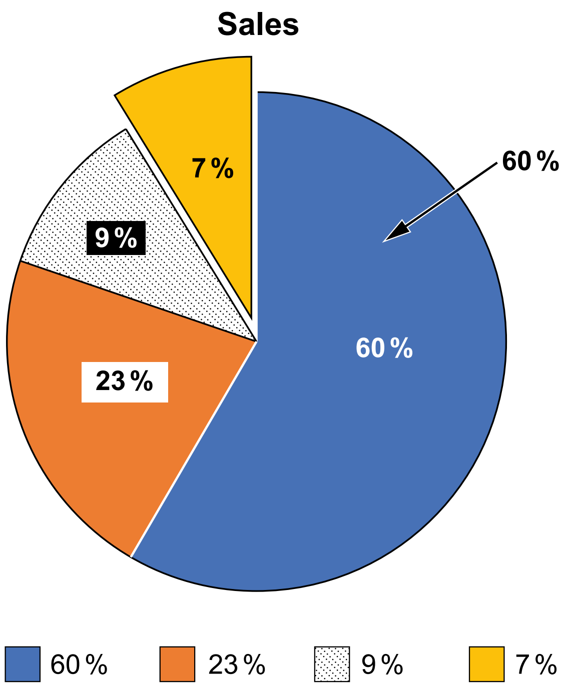


Figure 6a – normal colour vision

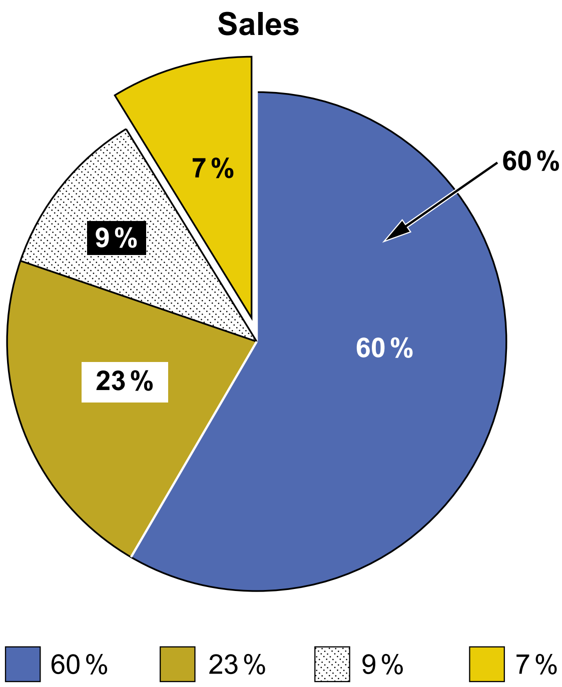


Figure 6b – 'colour blind' simulation of Figure 6a

- **Meeting minimum colour contrast ratios between label and background colour, adding labels (e.g. percentages) directly onto each segment**
  - alternative 1 – link each segment to a text label using arrows/lines
  - alternative 2 – add symbols/textures to each segment, add matching key, ensure:
    - (i) minimum colour contrast ratios are achieved between symbol/texture and background colour
    - (ii) size of patterns is large enough to be legible in the key
  - alternative 3 – to avoid the need for different text colours against light and dark background colours, create labels of one text colour, for example black against a white background 'sticker' (see also Figures 10a and 10b)

Note that in Figures 6a and 6b the key is not large enough and some colours are too similar. This reinforces the importance of adding labels to individual segments.

Examples of commonly used resources likely to create challenges for designers and CVD candidates

When designing supporting resources, it is essential to remember that candidates with CVD find it extremely difficult to retain 'colour' information when moving their focus between a key of different colours and the main elements of a diagram/graph/chart, etc. This creates a significant demand on working memory and will induce anxiety. Although it might be possible for candidates with CVD to be able to tell, from slight differences in shade and differences between colours in a colour key, they may find it difficult to apply these differences to identify the 'matching' colours in the chart. It might also be possible for them to be able to identify larger blocks of single colours but not smaller patches of colour, for example to identify a large country as matching but not a group of islands.

The most commonly used coloured resources that can create challenges for colour blind candidates are:

- **Graphs and charts (Figures 6a and 6b, 7a and 7b, 8a–d, 9a and 9b)**, including bar charts, kite graphs, line graphs, pie charts, population pyramids, proportional symbols, scatterplots and triangular graphs
- **Maps and plans (Figures 1a and 1b, 2a–d, 3a and 3b, 10a and 10b, 14a–d)**, including basic maps, choropleth maps, dot maps, Goad plans, isoline maps, public transport maps and road maps
- **Diagrams (Figures 11a and 11b, 15 and 16)** in particular, science and design and technology diagrams
- **External resources (Figures 12, 13a and 13b, 14a–d)**, including GIS maps, Ordnance Survey extracts, photographs and satellite images
- **Miscellaneous (front cover images, Figures 4a and 4b, 15 and 16)** including paintings and other artworks, posters/brochures/advertisements, media and film

For each type of resource above consider the comments at the corresponding Figures.

Graphs and charts

Bar charts

For bar charts and pie charts, someone with normal colour vision can instinctively and automatically see the order of the colours in the key and know whether or not they match the order of the bars/segments. In Figure 7a, the colours in each bar are in the same order from bottom to top as the colours in the key, reading from top left to bottom right. A candidate with colour blindness cannot be sure this is the case.

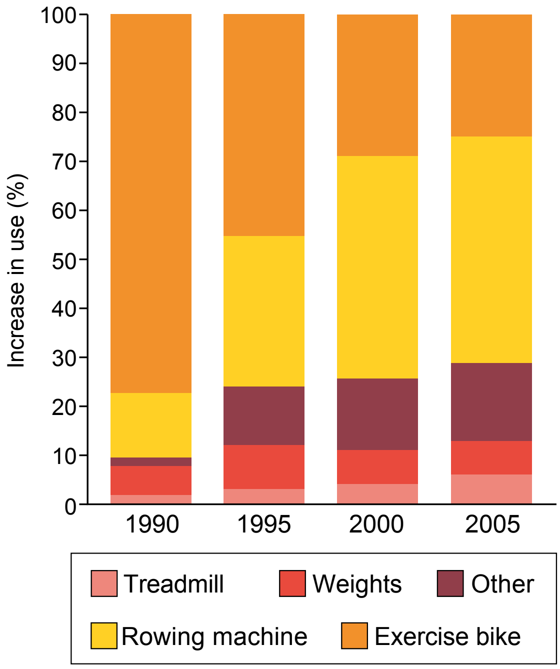


Figure 7a – normal colour vision

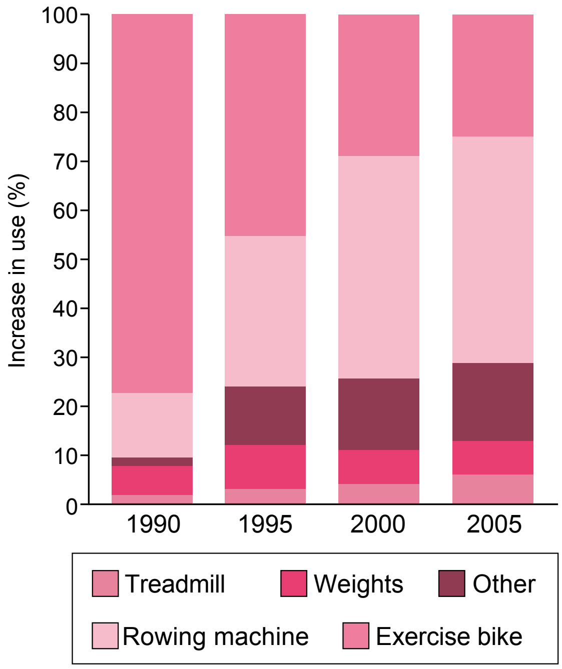


Figure 7b – 'tritanopia' simulation of Figure 7a

Figures 8a, 8b, 8c and 8d demonstrate how colour-only bar charts can be altered to ensure good practice. In Figure 8c all the colours have also been distinguished by different textures that contrast strongly with the background colours. The key also contains the different textures at a scale which is legible and provides further information about each colour/pattern in the key. However, it is important to be aware that the 'finished' scale will be relevant to how legible patterns and hatching will be seen (see Figures 3a and 3b, and 8c and 8d).

See also 'Tips for accessible keys' at page 12 and 'Tips for accessible labelling' at pages 28 to 29.

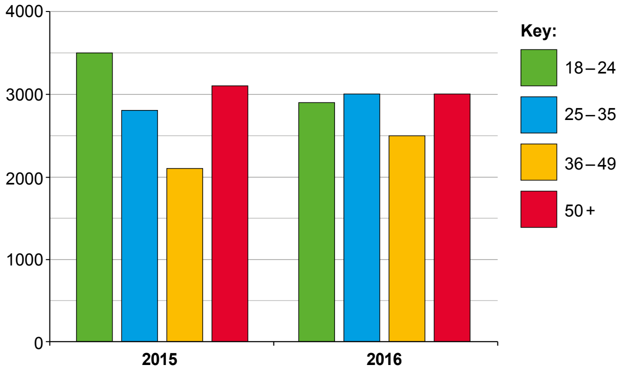


Figure 8a – normal colour vision

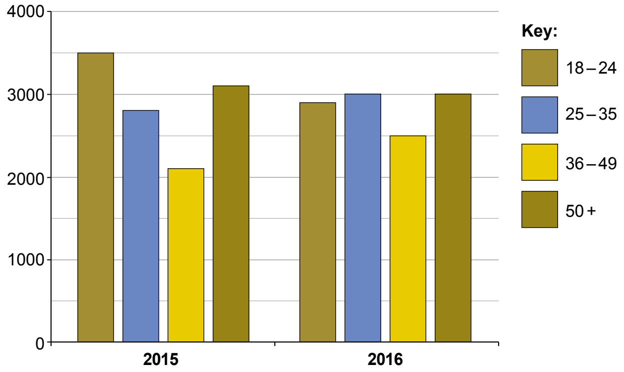


Figure 8b – ‘colour blind’ simulation of Figure 8a

Figures 8a and 8b demonstrate that colour-only graphs and charts that rely on colour-only keys to convey information are not appropriate for colour blind learners. Figures 8c and 8d demonstrate how colour-only charts can be adapted to ensure information is accessible to colour blind learners.

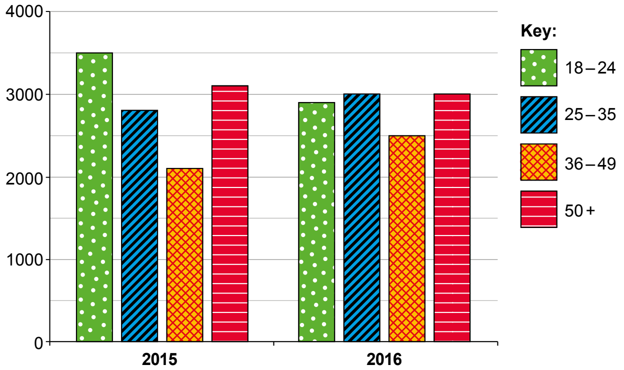


Figure 8c – normal colour vision

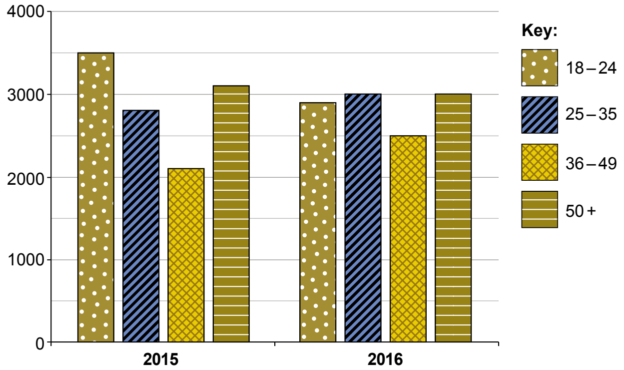


Figure 8d – ‘colour blind’ simulation of Figure 8c

Line graphs

Coloured line graphs can be easily adapted to ensure they are fully accessible. Where lines do not cross, each line can be labelled in text. However, if lines do cross, it is essential that each line is given a different pattern to ensure it can be followed before and after the intersection. Ensure each line pattern is reflected in the key. Lines themselves can also be designed to be a different pattern, for example dotted, dashed, dot/dash, or separate shapes can be added along the length of each line meaning information can be easily conveyed without the need for colour (see Figure 9a).

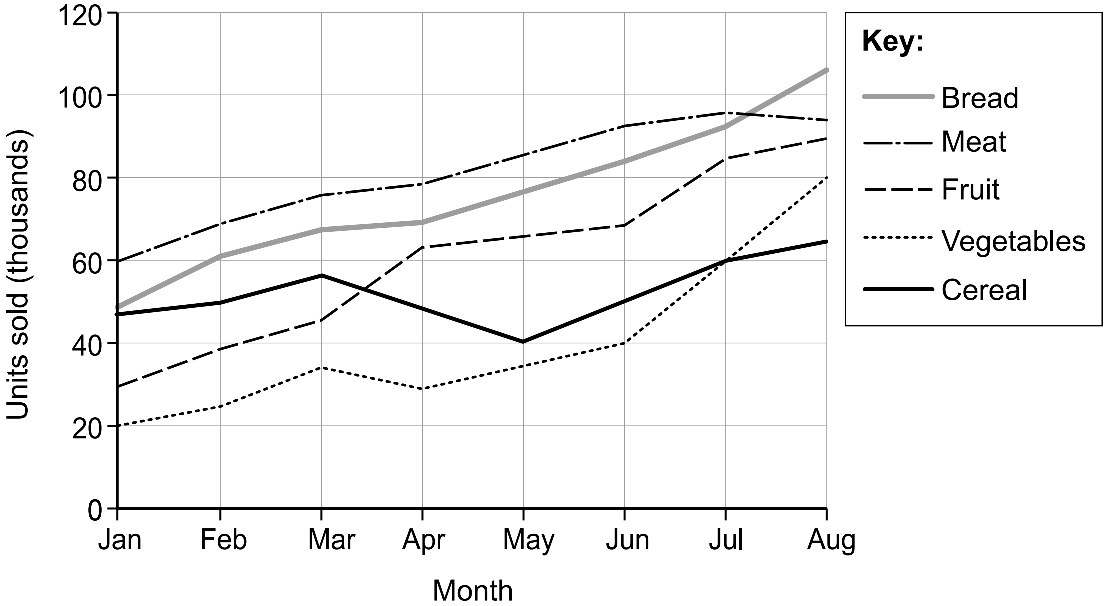


Figure 9a – line graph in greyscale using different patterns to distinguish between lines – good practice

Refer to the good practice example of a coloured line graph at Figure 9b. Different shapes are used to differentiate the entire lengths of different lines and, because the lines are also clearly labelled and include shapes, the lines/shapes can be any colour and shape. Using this technique, you can include as many coloured lines as necessary but take care that the shapes are legible within the finished printed scale of the graph.

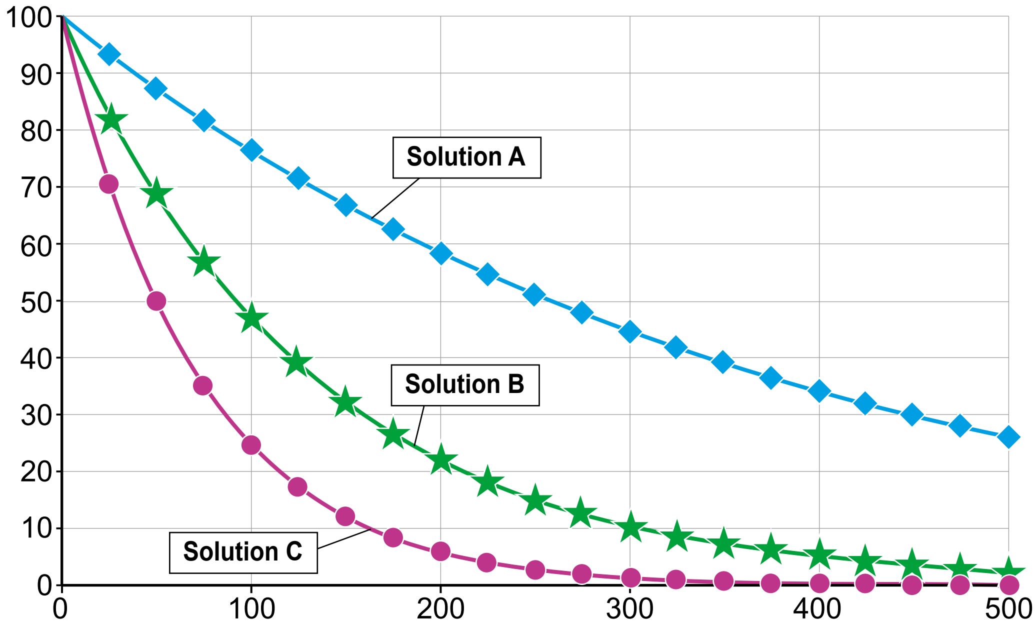


Figure 9b – good practice example of a coloured line graph

Pie charts

Good practice techniques for pie charts are discussed at page 20. See also Figures 6a and 6b.

Proportional symbols/dot maps/scatterplots

Proportional symbols can be very confusing when different coloured dots are used in addition to dots of one colour shown in different sizes. To avoid confusion:

- Do not use both different coloured dots and different sized dots of the same colour on the same chart.
- Avoid overlaying the same shape with one of a different size – where this cannot be avoided, separate shapes to make them distinguishable by using highly contrasting outlines.
- Consider whether information might be better represented by other means, for example within a table.

Tips for accessible dot maps and scatterplots

Scatterplots can be very effective if different, distinguishable shapes are used to identify different types of information:

- Avoid using different colours for the same shape – each shape should be a single colour.
- Avoid using shapes that can be confused, for example squares and diamonds.
- For scatterplots containing a lot of information, it may be useful to split information across two charts rather than creating one chart that is overly complicated.

Maps and plans

When selecting or creating maps, keep the information on the map as simple as possible to minimise the risk of confusion.

Avoid small patches of colour that are not necessary for the question.

Review Figures 1a and 1b, 2a–2d, 3a and 3b, 10a and 10b and 14a–d as examples of commonly used maps in examination papers.

Choropleth, isoline and heat maps

Figures 10a and 10b demonstrate good practice techniques to be used when creating choropleth, isoline and heat maps.

- Strongly contrasting lines mark the boundaries between different areas. In particular, white is used against dark backgrounds and black is used against light backgrounds to ensure minimum colour contrast ratios are maintained.
- Major cities are labelled in a text box that strongly contrasts with the background colour. The text box is also edged in a strongly contrasting colour to ensure it can be seen against any background colour.
- 'Rainfall' figures for each different section are presented as white numbers, which strongly contrast against the black background of a text box. The text boxes are edged in white to ensure the information is clearly visible against all background colours.
- Hatched lines are white against the darker surface (red) and black against the lighter surface (mustard yellow) to ensure minimum colour contrast ratios are achieved between the colour of the hatched lines and the background colour.

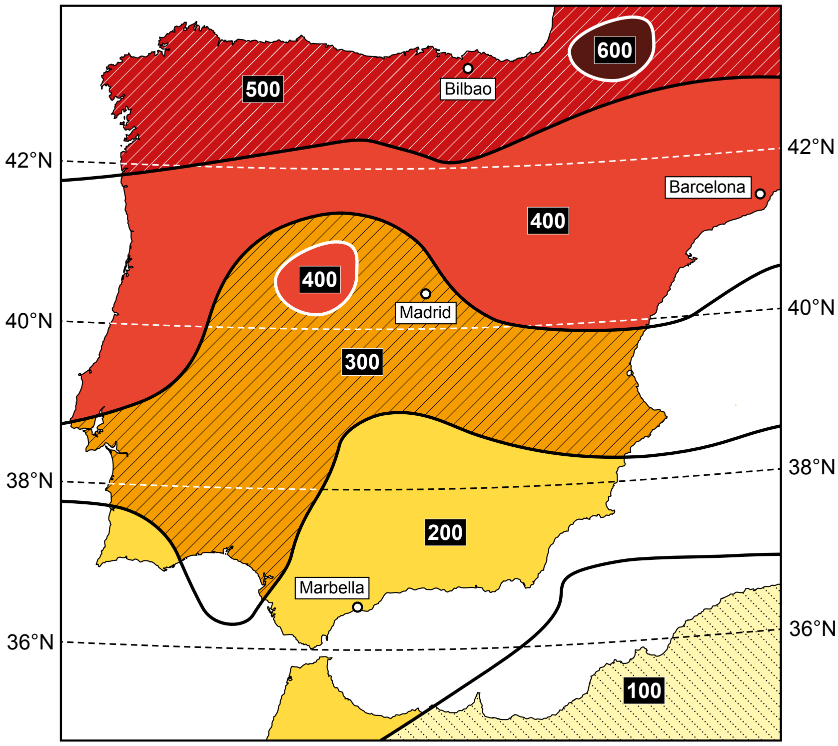


Figure 10a – normal colour vision

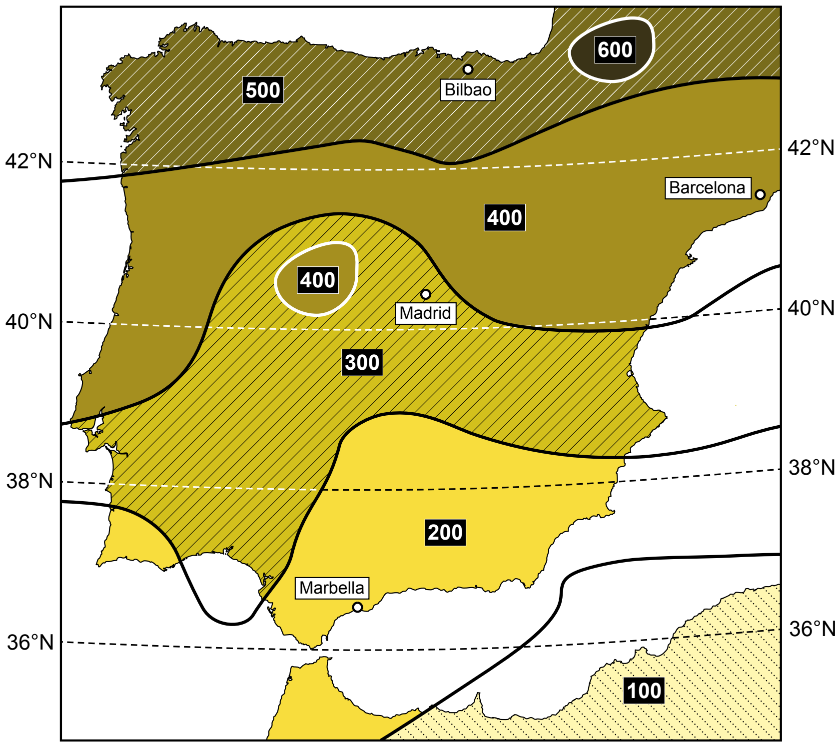


Figure 10b – 'colour blind' simulation of Figure 10a

Other good practice techniques for maps and plans:

- Use thick lines to denote important boundaries/roads and avoid confusion with other less important lines.
- Keep maps simple – only focus on important information (refer also to Figures 14c and 14d).

Tips for accessible labelling

Coloured diagrams can be very confusing for colour blind learners. Figures 11a and 11b demonstrate the importance of clear labelling for coloured diagrams. When creating a coloured diagram, it is best practice to label it on the assumption that candidates will 'see' it in greyscale. This will ensure all labelling is clear for all types of colour blind learner. See the good practice examples at Figures 11a and 12.

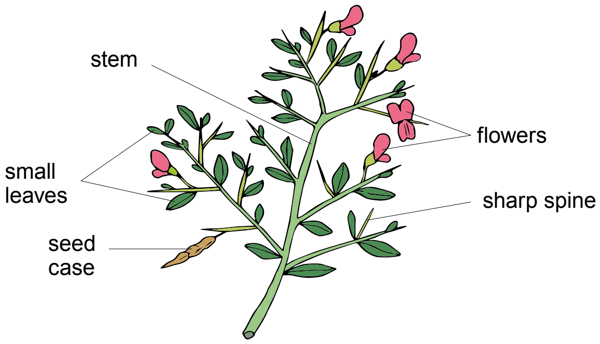


Figure 11a – normal colour vision

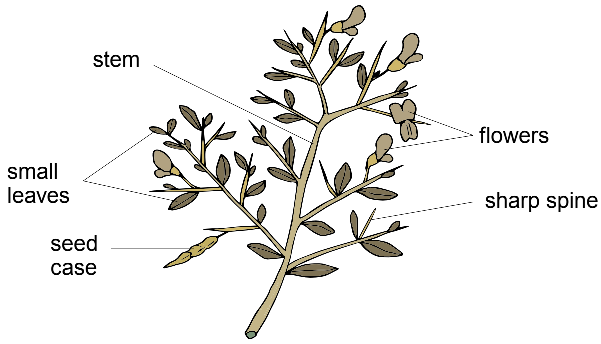


Figure 11b – 'colour blind' simulation of Figure 11a

When labelling diagrams and charts, it is preferable to avoid placing labels over images. If this is not possible:

- Consider the position of the line from the text label to the location on the diagram.
- Check lines cannot be confused because of lack of contrast along part of their length, for example avoid black lines over dark colours and reverse out in white, if necessary, to provide clarity.
- Ensure any arrow heads are a consistent size and style and meet minimum colour contrast ratios against all background colours.
- Ensure lines from text labels meet minimum colour contrast ratios against all background colours.
- Consider stroke weights – heavier weights may be more prominent.
- Consider the addition of a strongly contrasting outline (a halo effect) around arrows to ensure their entire length and any arrowhead can easily be seen against all background colours, as in the good practice example at Figure 12.
- Avoid changes in colour along the length of an arrow shaft.
- Any hatching/textures/text/symbols used must meet minimum colour contrast ratios against background colours.
- Use solid coloured text boxes with strongly contrasting text if placing text across coloured backgrounds (refer to Figures 6a and 6b, and 10a and 10b for good practice labelling techniques).

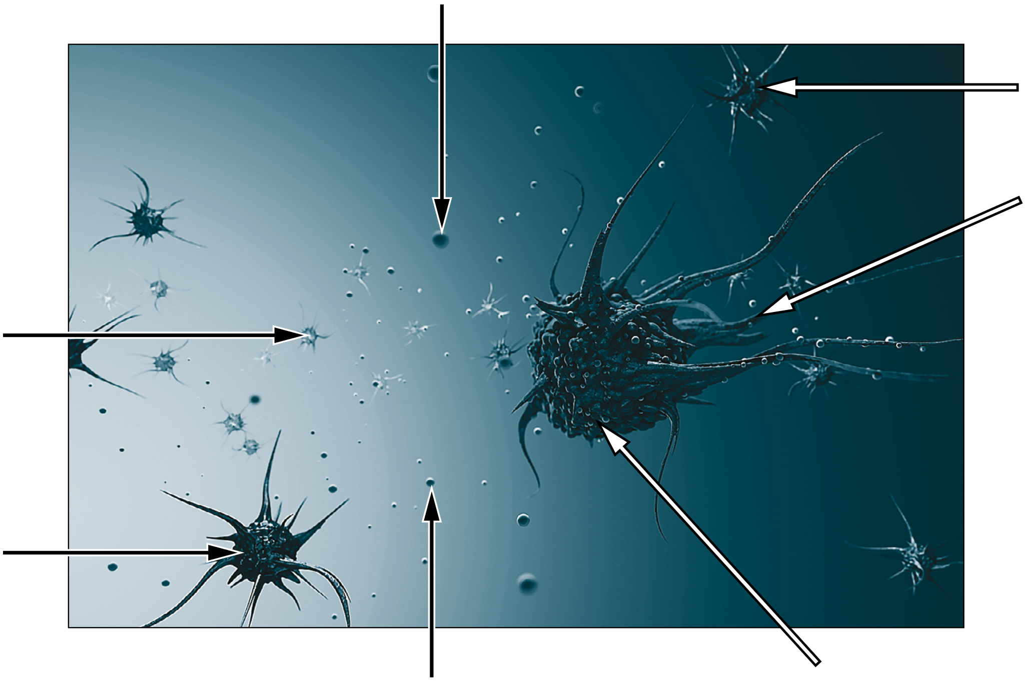


Figure 12 – good practice example of labelling with arrows

Figure 12 is a good practice example to demonstrate how labelling with arrows can be effective because it makes use of outlining the full length of the arrow shafts. The detail of the arrow heads is also in a strongly contrasting colour. White arrows with black outlines are used over darker backgrounds whilst black arrows with white outlines are used over lighter backgrounds. Contrast this with the example at Figures 13a and 13b.

See also 'Tips for accessible keys' at page 12.

Photographs/posters, technical charts and diagrams

Photographs/posters, technical charts, diagrams and other similar original resources may require annotation to ensure important information is accessible.

When selecting photographs and technical charts, **review them in greyscale** in the first instance.

Where there is potential for ambiguity, consider adding a combination of:

- labels and/or
- text boxes and/or
- outlining important elements in a highly contrasting colour (preferably white against dark backgrounds and black against light backgrounds).

When annotating, refer to the 'Tips for accessible labelling' at pages 28 to 29.

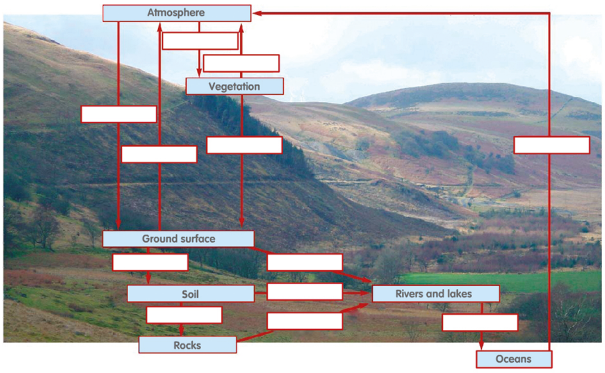


Figure 13a – normal colour vision

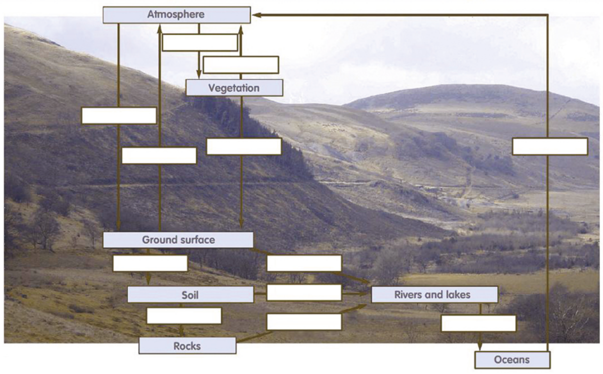


Figure 13b – 'colour blind' simulation of Figure 13a

In Figure 13a, copying into greyscale would have shown that the red arrows are not suitable. The solution would be to replace the red arrows and lines with arrows and lines in a strongly contrasting colour such as white (see Figure 12).

Miscellaneous external resources (items that cannot be manipulated)

Selection of suitable resources such as Ordnance Survey extracts, posters, advertisements, etc. at the outset of the question paper development process is essential.

If you are unsure about the legibility of information when choosing resources, copy it into greyscale as a first step. Resources should still achieve minimum colour contrast ratios even in greyscale because of the way people with colour vision deficiencies perceive contrast differently to people with 'normal' colour vision. For example, pale grey text against a white background is likely to be legible for people with normal colour vision but to people with CVD it can be almost invisible, especially when reproduced in digital format.

Note also that when papers are added to WJEC website as online materials they must meet The Public Sector Bodies (Websites and Mobile Applications) (No. 2) Accessibility Regulations 2018 (see References). If they don't, an accessible alternative must be provided. This will have cost implications and is a waste of time/resources when suitable, original materials can be chosen at the outset.

Tips for selecting external resources

Resources should only be selected for a task if they are relevant to the assessment construct.

- Information such as coloured headings against coloured backgrounds must meet minimum colour contrast ratios.
- Avoid ambiguity in the chosen image by adding clear labels.
- Also consider the scale of the information in the original. A poster at A0 scale may be much easier to read than a replication at A5 scale.

Refer also to 'Tips for accessible labelling' at pages 28 to 29.

Ordnance Survey extracts

When using Ordnance Survey extracts consider creating questions that can satisfy the requirements of the Specification whilst not excluding CVD candidates. Use areas of OS maps in which no information is given in colour only and also consider the following points:

- If contour lines (brown) run over a green background (e.g. a wooded area), select a different area of the map where contour lines are legible against the white background.
- Select extracts where road numbers are given – don't rely on colour only to indicate different types of road.
- Try simulating the OS map key into greyscale as this can help to identify potential colour confusions before you select suitable extracts.
- Avoid overlaying extra information in colour onto OS extracts.
- Where testing ability to interpret coordinates, select an extract that does not contain information overlaid with colours.

Figures 14a and 14b demonstrate why overlaying information onto OS extracts is not usually appropriate. Consider whether using a bespoke, simple map (rather than trying to adapt an already cluttered resource) would have been a better option here (see Figures 14c and 14d).

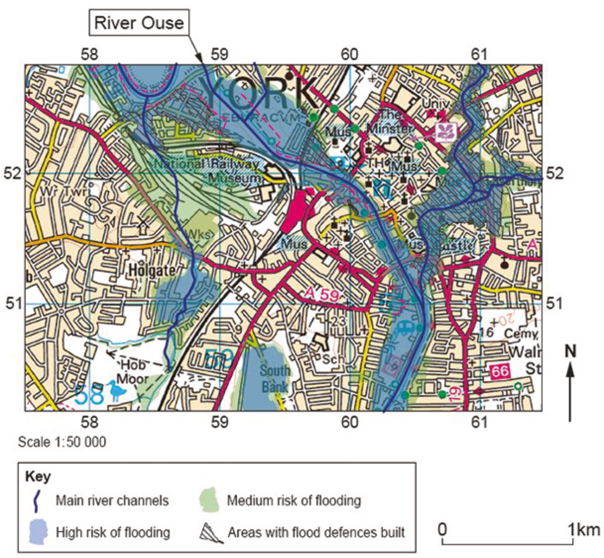


Figure 14a – normal colour vision

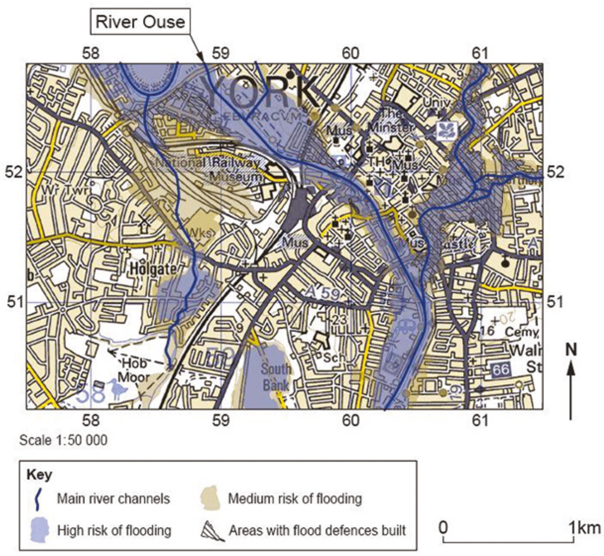


Figure 14b – 'colour blind' simulation of Figure 14a

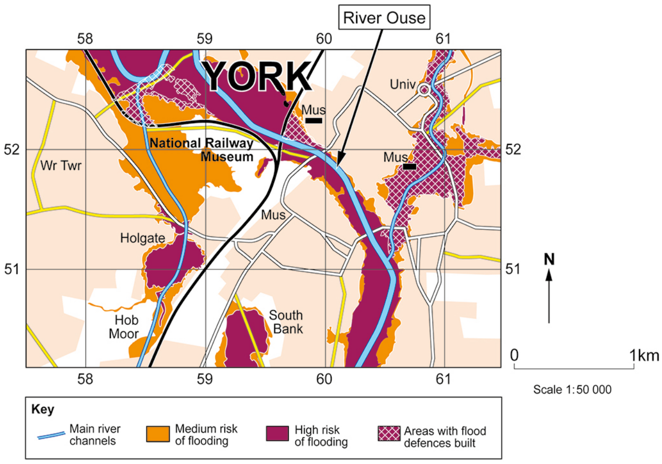


Figure 14c – normal colour vision

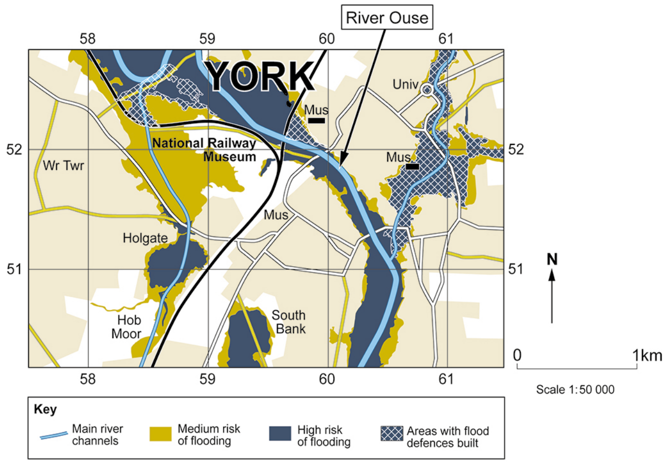


Figure 14d – 'colour blind' simulation of Figure 14c

Posters/advertisements/video clips

The range of potentially available resources is almost infinite, therefore always keep the tips at page 9 in mind from the outset when designing an assessment.

Figure 15 is a good practice example because:

- although different colours are used, these are not essential to the understanding of the information provided;
- the symbols, icons and arrows have strong colour contrast with background colours; and
- the text contrasts strongly with background colours; note in particular that different coloured text has been used depending upon the colour of the background, to ensure all text exceeds minimum colour contrast ratios against background colours.

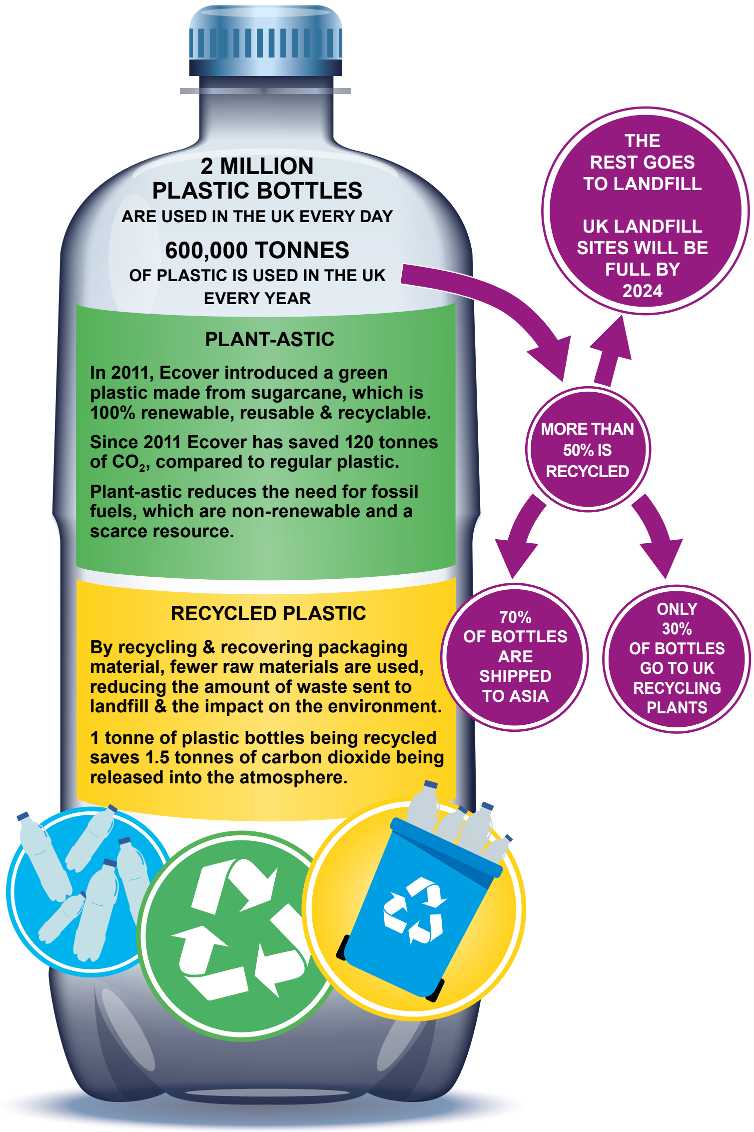


Figure 15 – good practice example

Figure 16 at page 34 also demonstrates some good practice techniques but there are also elements that could be improved.

Good practice techniques

- Some text (e.g. black versus light blue) exceeds minimum colour contrast ratios versus background colour.
- Some text and symbols have been outlined in a strongly contrasting colour to ensure information is legible against background colours (e.g. **30 min** in white text has been edged in black to ensure it can be read against the yellow background). The red and green arrows have been edged in a strongly contrasting colour.
- Some symbols (e.g. swimmer activity rate icons) contrast strongly with the background colour.
- The coloured lines alongside the swimmer's limbs, which denote different health benefits, are clearly labelled.

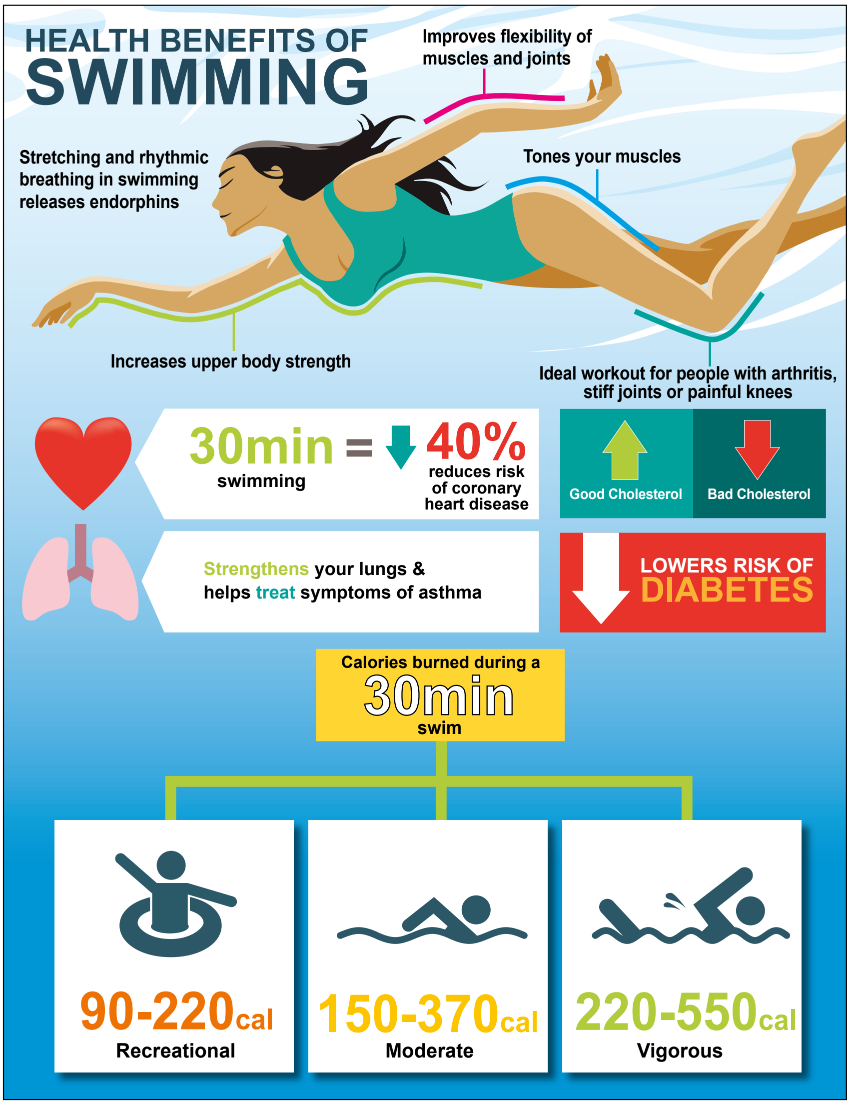


Figure 16

Elements that could be improved

- Yellow and pale green colours have insufficient contrast with the background (white) and may be illegible to some learners with CVD.
- Orange text ‘diabetes’ against the red background has insufficient contrast and should either be in a different, strongly contrasting colour, or be outlined in a strongly contrasting colour.

For more information refer to the Checklist, Definitions and Further Information sections in Part 3.

PART 3

Checklist

Below is a general summary of the information in this Guidance and the key points to remember when selecting and designing any resources where the use of colour is necessary.

Remember

- Never convey information by colour alone.
- Keep it simple.
- There is no such thing as a ‘safe colour palette’ for CVD.
- Don’t make assumptions that just because two colours look distinctly different to you, that they will to CVD candidates.
- Before resources are accepted, colour contrast ratios between different elements will be checked with software (by the Graphics Team) – see list below.
- You may need to justify the use of colour (integral, useful or incidental).

Considerations for the Graphics Team

- Always start by designing in greyscale.
- Next add text, shapes, symbols, textures, etc.
- Only add colour where it is essential or useful.
- Re-check your finished designs by simulating into greyscale.
- Designs can be checked using a simulator but if you do use a simulator tool, remember
    (i) to check for all types of CVD, including greyscale; and
    (ii) such simulations can only give an indication – they are never 100% accurate.
- Where colour must be used, colour contrast ratios must be checked to ensure minimum AA rating requirements are met
    (i) between all colours that convey information, for example different segments of pie charts or bars in a chart;
    (ii) between all colours and the background colour, for example between pie chart segments and the colour of the paper; and
    (iii) between any text/labels and background colour, for example arrows on a diagram or labels on a poster.
- Check any patterns/texture used in charts, etc. are also matched to the colours of the key in a size that is legible.
- Avoid using
    (i) red as a contrast to black or brown;
    (ii) pastel colours; and
    (iii) pale grey.
- Refer to http://www.colourblindawareness.org/colour-blindness/types-of-colour-blindness/ for a list of common colour combinations to avoid but note this is not an exhaustive list and should only be referenced as a starting point.
- You may have to sacrifice some design niceties, such as having all text in a single colour, because it may be necessary to use white text against dark colours and black text against paler colours in order to satisfy minimum colour contrast ratios.

Further information

For further information on colour blindness, including Resources for teachers, refer to the Colour Blind Awareness website www.colourblindawareness.org. You can watch videos on the impacts on colour blindness in education on the Colour Blind Awareness YouTube channel – in particular the #1ineveryclassroom video here https://www.youtube.com/watch?v=0F01Q0581pI.

Definitions and terminology

AA rating – the minimum colour contrast ratio to be applied between two colours to ensure accessibility for people with CVD. See WCAG 2.1 below. WCAG 2.1 has three ratings standards – A, AA and AAA. The AA rating ensures sufficient colour contrast for all types of CVD and caters to 20/40 vision i.e. for those with visual impairments who don't use assistive technology.
For text of 18pt or smaller, the minimum colour contrast ratio for AA rating is 4.5:1.
For text larger than 18pt, the minimum colour contrast ratio for AA rating is 3:1.

The AAA rating is more onerous and stipulates a minimum colour contrast ratio of 7:1. This ratio is recommended for all body text.

Colour contrast ratios can be calculated easily using a variety of free, downloadable software packages to suit individual needs (see References).

Access Arrangements – Access Arrangements are agreed before an assessment. They allow candidates with special educational needs, disabilities or temporary injuries to access the assessment and show what they know and can do without changing the demands of the assessment. The intention behind an Access Arrangement is to meet the particular needs of an individual candidate without affecting the integrity of the assessment. Access Arrangements are the principal way in which awarding bodies comply with their duty under the Equality Act 2010 (see References) to make 'reasonable adjustments'. Although Access Arrangements are normally agreed in advance of an assessment, for candidates who have no other needs except colour blindness, arrangements do not need to be notified to the exam board in advance.

Anomalous trichromacy – a milder form of colour vision deficiency where one type of cone cell does not function normally, affecting ability to perceive many colours.

Colour blindness – a colloquial term for colour vision deficiency.

Colour contrast ratio – the difference in colour contrast between two colours. This is usually calculated during the design process using bespoke software to check accessibility requirements are met. Minimum colour contrast ratios for colour blindness accessibility are specified in accordance with World Wide Web Consortium (W3C) Guidelines: https://www.w3.org/TR/WCAG21/.

Colour vision deficiency (CVD) – generally an inherited condition that creates an abnormality, or deficiency, of any of the types of cone cells and results in abnormal colour vision (the inability to perceive colours normally). There are three basic variants of colour vision deficiency depending on which cone cells are affected – protan, deutan and tritan deficiencies. Milder forms of colour blindness are known as anomalous trichromacy, where all the cone types work but one type does not function normally.

Colour vision screening – testing for colour vision deficiencies using the Ishihara test. This was undertaken routinely in many schools at school entry until 2009.

Cones – specialised nerve cells (photoreceptors) within the retina at the back of the eye. There are three types of cone cells in humans that respond differently to different light wavelengths, absorbing red, blue and green light respectively. The cone cells work together and are responsible for colour vision.

Coping strategies – the behavioural and cognitive efforts made by individuals in attempting to deal with stressful situations.

Deuteranomaly – a form of anomalous trichromacy where cone cells that should absorb green light don't function normally.

Deuteranopia – a severe form of colour vision deficiency, dichromacy, where there are no functioning cone cells to absorb green light.

Dichromacy – a severe form of colour vision deficiency where one cone type doesn't function at all.

Dichromat – a person who has dichromacy, i.e. protanopia, deuteranopia or tritanopia.

Disability – The social model of disability says that disability is created by physical, sensory, intellectual, psychological and attitudinal barriers. The social model identifies solutions to remove or reduce these barriers within society, rather than trying to fix an individual's impairment or health condition. The social model is the preferred model for disabled people. It empowers disabled people and encourages society to be more inclusive. For the purposes of disability legislation, it is widely accepted that a person has a disability if they have a physical or mental impairment that has a substantial and long-term effect on their ability to carry out normal day-to-day activities affecting one or more of several categories including 'speech, hearing or eyesight'. It is important to remember that colour blind people face hidden barriers and can be considered to have a disability.

Inclusive – not excluding any of the parties or groups involved in something.

Indirect sexual discrimination – it is indirect sexual discrimination to have a rule, policy or practice that someone of a particular sex is less likely to be able to meet; thereby placing them at a disadvantage to a different sex.

Integral – necessary to make a whole complete; essential or fundamental.

Ishihara test – a simple screening test to establish whether a person has a form of red or green colour vision deficiency: https://en.wikipedia.org/wiki/Ishihara_test.

Minimum colour contrast ratio – the minimum recommended contrast ratio between two colours to meet the requirements of WCAG 2.1. The minimum ratio varies depending upon the rating level being applied. There are different minimum colour contrast ratios for different rating levels depending upon the size of font etc. For more information see WCAG 2.1. To ensure accessibility for people with colour blindness the minimum colour contrast ratio must never be less than 3:1.

Protanomaly – a form of anomalous trichromacy where cone cells that should absorb red light don't function normally.

Protanopia – a severe form of colour vision deficiency, dichromacy, where there are no functioning cone cells to absorb red light. Due to the lack of cone cells absorbing red light someone with protanopia will have a shortened visible spectrum and will perceive many reds as black.

Reasonable adjustments – The Equality Act 2010 (see References) requires an awarding body to make reasonable adjustments where a candidate, who is disabled within the meaning of the Equality Act 2010, would be at a substantial disadvantage in comparison to someone who is not disabled. The awarding body is required to take reasonable steps to overcome that disadvantage (see link to JCQ in References). JCQ Instructions for Conducting Examinations permit colour blind candidates to use a colour chart. Colour charts will NOT help candidates with colour blindness and should be avoided.

'Red/green' colour blindness – a misnomer. It is a common misconception that all people with colour blindness have 'red/green' colour blindness and confuse only reds and greens. This may be because people with protan and deutan types of colour blindness most commonly experience problems distinguishing between reds and greens. However, red/green colour blindness is not a specific condition – it is a term that encompasses mild to severe forms of both protan and deutan deficiencies. People with protan and deutan deficiencies don't just experience problems distinguishing between reds and greens, many colour combinations can be confused.

Safe colour palette – a misnomer. A safe colour palette would be a suite of colours within which everyone with colour blindness could distinguish between all colours used. This may be achievable only in very limited circumstances involving no more than three colours in addition to black and white. This is due to the need for minimum colour contrast ratios of at least 3:1 to be achieved between all colours.

Trichromacy – the ability to see colours normally, i.e. all three cone types function correctly.

Tritanopia – a severe form of colour vision deficiency, dichromacy, where there are no functioning cone cells to absorb blue light. A person with tritanopia will experience difficulties distinguishing between blues and yellows in particular.

WCAG 2.1 – The International Accessibility Standards were updated in August 2018 to version WCAG 2.1 (see References) and have three ratings standards – A, AA and AAA. AAA is the most onerous and AA is the minimum standard that must be met to ensure people with colour blindness can fully access information. WCAG 2.1 is equivalent to European Standard ETSI EN 301 549 and is also incorporated into the UK's The Public Sector Bodies (Websites and Mobile Applications) (No. 2) Accessibility Regulations 2018 (https://www.legislation.gov.uk/uksi/2018/952/introduction/made), which apply to some exam boards and to all public sector bodies. Check https://www.w3.org/ for the latest updates of WCAG. At the time of publishing this Guide, WCAG 2.2 is currently under development.

References

- Achromatopsia – http://www.achromatopsia.info/achromat-vision/
- Equality Act 2010 – https://www.gov.uk/guidance/equality-act-2010-guidance
- Colour Blind Awareness – http://www.colourblindawareness.org/
- Fair Access by Design – https://www.qualificationswales.org/english/information-for-stakeholders/for-awarding-bodies/fair-access-by-design/
- JCQ (Joint Council for Qualifications) – https://www.jcq.org.uk/
- The Public Sector Bodies (Websites and Mobile Applications) (No. 2) Accessibility Regulations 2018 – https://www.legislation.gov.uk/uksi/2018/952/introduction/made
- UKAAF (UK Association for Accessible formats) – https://www.ukaaf.org/
- Web Content Accessibility Guidelines WCAG 2.1 – https://www.w3.org/TR/WCAG21/
- **Software resources for calculating colour contrast ratios**
  https://axesslab.com/top-color-contrast-checkers/?action=preload/
  https://snook.ca/technical/colour_contrast/colour.html#fg=33FF33,bg=333333
  https://juicystudio.com/services/luminositycontrastratio.php
- **Simulation software**
  https://www.makeuseof.com/tag/3-easytouse-online-colorblindness-simulators/
  https://colororacle.org/
  https://www.adobe.com/accessibility/products/photoshop.html

Further reading

- https://www.gov.uk/service-manual/helping-people-to-use-your-service/making-your-service-accessible-an-introduction#meeting-government-accessibility-requirements

- https://blogs.lse.ac.uk/impactofsocialsciences/2017/07/31/its-time-designing-for-the-colour-blind-became-a-more-integrated-component-of-academic-and-media-training/
- https://www.adcet.edu.au/resource/10388/universal-design-in-education-colour-vision-deficiency/?fbclid=IwAR3cxWrI5V-rDJjbsDh91eZfUcB_p69FuBkorWeX6mJDYnS-DIOwud7E3mo

Sources for all images

Front cover – Colour Blind Awareness CIC
Figure 1a – WJEC, GCE AS/A LEVEL (Legacy) GEOGRAPHY – G1 Changing Physical Environments, Summer 2017, S17-1201/01 (adapted)
Figures 2a, 2c and 2d – produced by the WJEC for the purposes of this Guidance
Figure 3a – produced by the WJEC for the purposes of this Guidance
Figure 4a – Colour Blind Awareness CIC
Figure 5 – produced by Colour Blind Awareness CIC and the WJEC for the purposes of this Guidance
Figure 6a – produced by Colour Blind Awareness CIC and the WJEC for the purposes of this Guidance
Figure 7a – produced by the WJEC for the purposes of this Guidance
Figures 8a–8d – produced by Colour Blind Awareness and the WJEC for the purposes of this Guidance
Figure 9a – produced by the WJEC for the purposes of this Guidance
Figure 9b – produced by the WJEC for the purposes of this Guidance
Figure 10a – produced by the WJEC for the purposes of this Guidance
Figure 11a – WJEC, GCSE SCIENCE (Double Award) Unit 4 – BIOLOGY 2 FOUNDATION TIER, Summer 2019, S19-3430U40-1
Figure 12 – Getty Images
Figure 13a – http://resource.download.wjec.co.uk.s3.amazonaws.com/vtc/2012-13/geography/dfes-01/core/activities/a-physical/water/movement-of-water/eng/index.html#/page-1
Figure 14a – WJEC, GCSE GEOGRAPHY (Specification A) FOUNDATION TIER UNIT 1: Core Geography, Summer 2017, S17-4231/01
Figure 15 – WJEC, GCSE ENGLISH LANGUAGE UNIT 3 Reading and Writing: Argumentation, Persuasion and Instructional, Summer 2019, S19-3700U30-1A
Figure 16 – WJEC, GCSE ENGLISH LANGUAGE UNIT 3 Reading and Writing: Argumentation, Persuasion and Instructional, Autumn 2019, A19-3700U30-1A

Disclaimer

WJEC takes no responsibility for any software listed in this document. Any software listed in this document is downloaded at the users' risk.

Throughout this document where images are in pairs, 'colour blind' simulated images are shown on the right or underneath. Unless otherwise stated, these illustrative images mostly indicate severe red or green types of colour blindness and have been selected to demonstrate the specific points made within the text and according to the context of the original. No simulation software can be relied upon to be an accurate representation of the type of colour vision deficiency experienced by an individual with colour vision deficiency. For specific advice to support people with blue/yellow deficiencies or monochromacy, please contact Colour Blind Awareness directly (info@colourblindawareness.org). It is also acknowledged that not all colour blind people (due to their inability to distinguish between many different colours) will be able to experience all of the issues highlighted in the examples and simulations used in this document.

Appendix

Minimum colour contrast ratios – Additional guidance for Graphics Team

Minimum colour contrast ratios, which ensure accessibility for people with colour blindness, have been defined by the World Wide Web consortium. These ratios were originally designed for websites but are equally relevant for all information that will be designed digitally. These minimum colour contrast ratios are found within the Web Content Accessibility Guidelines WCAG 2.1 (see References).

Minimum colour contrast ratios **must** be met

- between all of the colours that are being compared, for example every different colour of a bar chart/pie chart/line graph/isoline colours;
- between each colour and the background colour of the paper; and
- between additional text, labels, texture, etc. and the background colour.

Maximum contrast is the key to accessibility for colour blind candidates, even when using greyscale (due to the different ways in which people with CVD perceive contrast). For example, those with severe forms of CVD often can't see pale grey text against white or may confuse pale grey with white sections of a chart. Likewise, darker greys can also be easily confused.

Colour contrast ratio is a technical calculation of the difference in colour contrast between two colours. Colour contrast ratios can be easily calculated by using specialist software (refer to References for a list of software packages that can calculate colour contrast ratios).

Before checking colour contrast ratios, you can run your designs through a colour vision simulator (see References for details). Firstly, check in 'greyscale' simulation, then remember to check for each type of colour blindness – protanopia, deuteranopia and tritanopia. This may sound complicated, but the software is usually straightforward and often allows you to view all four simulations and the original at the same time (see Figure 5).

However, it is important to remember that due to the different types of colour blindness, different computer settings and different algorithms within different software packages, NO SIMULATIONS ARE 100% ACCURATE. SIMULATIONS CAN ONLY GIVE AN **INDICATION** OF WHERE ISSUES MIGHT LIE; SO COLOUR CONTRAST RATIOS MUST ALSO BE CHECKED.

Small patterns, such as a 'dotted fill', will need to meet a minimum colour contrast ratio of 4.5:1 in order to be deciphered from coloured backgrounds, whereas a contrast ratio of 3:1 may be acceptable for larger symbols depending upon their size/thickness (refer to AA rating). See also Figures 8a–8d.

How to apply and check minimum colour contrast ratios

There are many software packages (refer to References) that can calculate colour contrast ratio. Some require colour specifications to be inputted in number format (e.g. RGB or Hex references for individual colours) and are useful for designers.

For those who want to carry out a simple check, more suitable software may have a 'dropper' function, which allows you to click on the foreground colour and then click on the background colour. The software will then automatically calculate the colour contrast ratio. Some packages have sliders that let you change the colours slightly until you find a combination that will meet the minimum ratios.

Experiment with the different types of software to find one that suits you. Some popular software design packages such as Photoshop have colour blind simulation functions pre-installed.

Remember to check all of the contrast ratios between all of the different colours that convey information, including text against background colour.