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The effect of abnormal colour vision on the ability to identify and outline coloured clinical signs and to count stained bacilli in sputum

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Aim: To determine if medical practitioners with congenital colour vision deficiencies (CCVD) are less able to identify and delineate the extent of coloured abnormal signs than those with normal colour vision.
Method: Twenty-two medical practitioners with CCVD and 17 with normal colour vision, matched for age and gender, were shown 10 photographs. They were asked to identify and outline the extent of the clinical sign in eight that were of vomit or stool (six of these showing fresh blood), one of a skin rash and for one to mark the position of bacilli in sputum stained by the Ziehl-Neelsen method.
Results: There were statistically significant differences between the CCVD practitioners and those with normal colour vision in their ability to outline abnormalities in five of the six photographs that showed fresh blood, in the photograph of a rash and in marking the position of bacilli in the photograph of a stained slide.
Conclusion: Medical practitioners with CCVD are handicapped in their evaluation of the presence and extent of coloured clinical signs. Medical schools should ensure that students with CCVD are aware of their deficiency and know its severity, so they can take special care in clinical practice.

Key words: colour in medical diagnosis, congenital colour vision deficiency, occupational handicap

Although congenital colour vision deficiency (CCVD) affects eight per cent of the male population in most Western countries and it is likely that its prevalence is similar in the medical profession,[1] few studies have considered its effects on the clinical decision-making process. Practitioners with CCVD have reported a wide range of difficulties encountered in clinical practice.[2-4] We have reported previously the reduced ability of medical practitioners with CCVD to detect[2-4] abnormalities presented in clinical photographs, and their reduced confidence in doing this compared with control practitioners.[5,6] Those with CCVD also tend to match coloured blocks in the colour range of a widely used blood glucose testing stick to a wider range of options than those with a less severe defect or controls.[7] This study aims to provide evidence of the effect of CCVD on the ability of the practitioner to identify and outline abnormalities in clinical photographs.

METHOD

As part of a larger study, the detailed methods have been presented previously.[5-7] Twenty-two medical practitioners with CCVD and 17 with normal colour vision, matched for age and gender, all male and none over the age of 60 years, were asked to outline and identify areas of abnormality on clear acetate sheets overlaying 10 photographs (125 mm by 90 mm) viewed at reading distance under white fluorescent tube lighting with a colour rendering index of 86, or in a North-facing window between 11 am and 1 pm. Photographs had been selected for inclusion in this study on the basis of data[2,4,8] on their likelihood of being associated with colour confusion by those with congenital red-green CCVD. They included three photo-

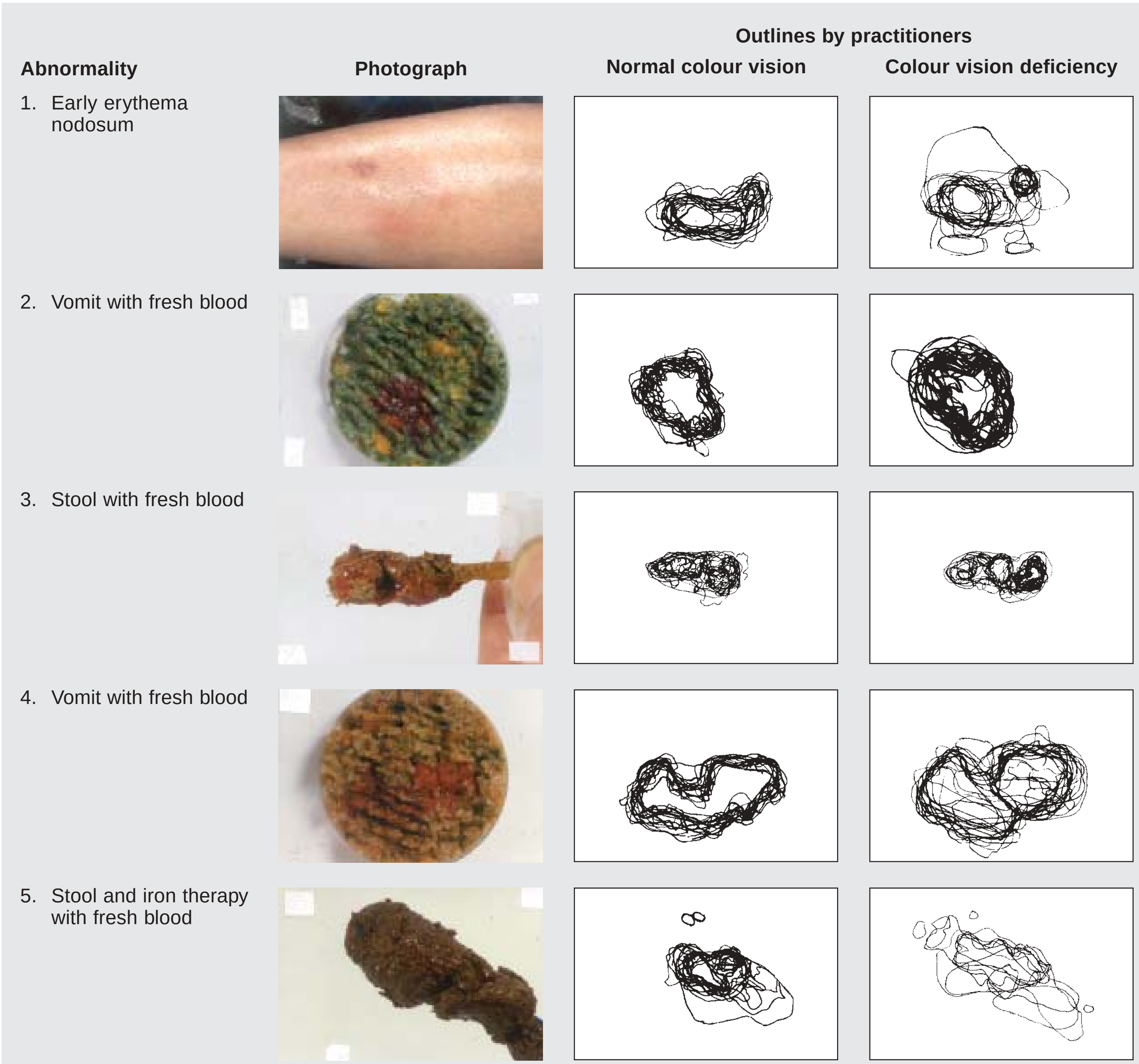


Figure 1. The 10 photographs, the first nine with superimposed outlines, by the 17 practitioners with normal colour vision (left), and the 22 with CCVD (right). One photograph of bacilli stained by the Ziehl-Neelsen method, with an example of positions of the bacilli marked by one practitioner from each group.

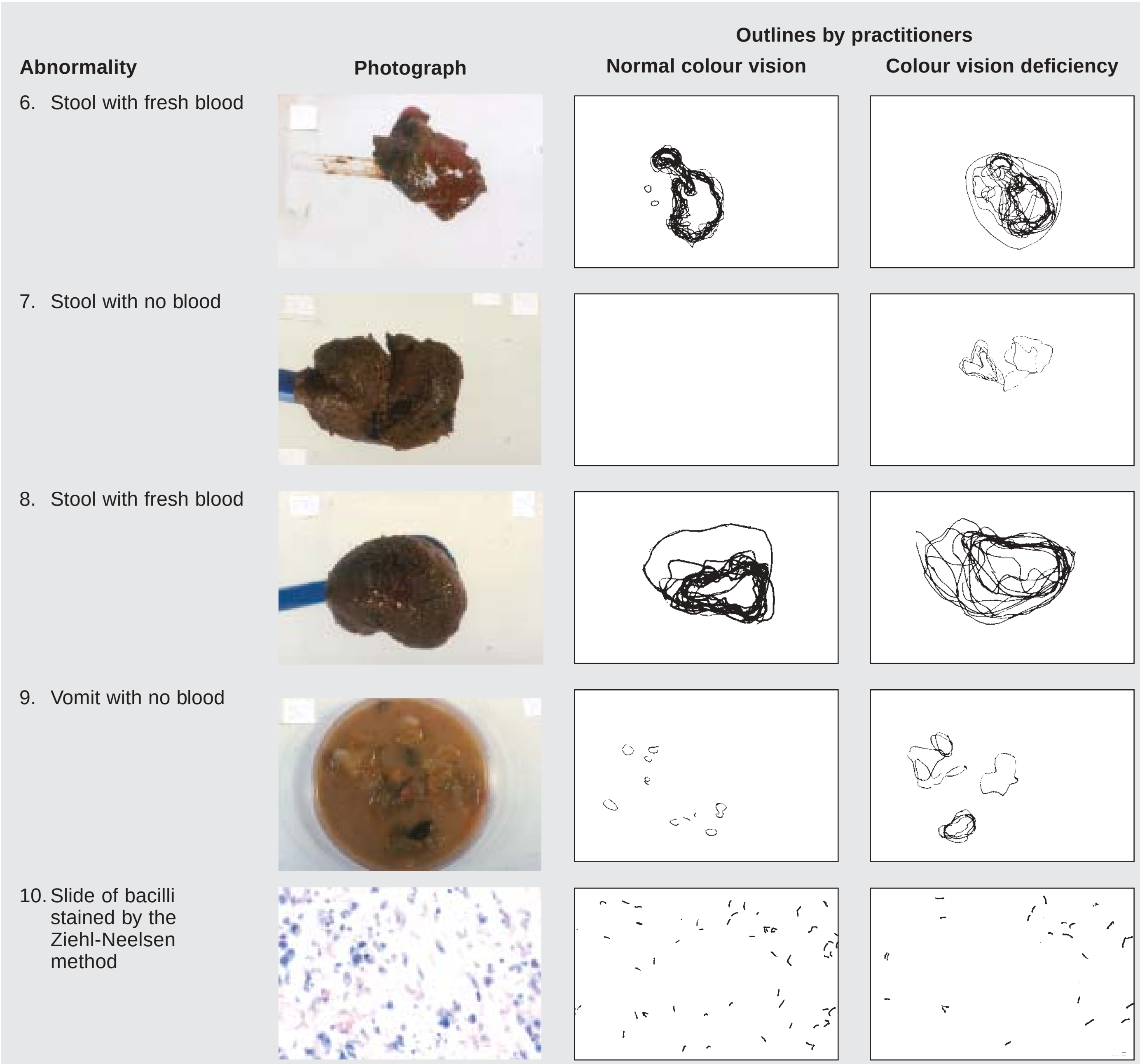


Figure 1 continued

graphs of vomit (two with fresh blood), five of stool (four with fresh blood), one of a skin rash and one of tubercle bacilli (x100 magnification) stained by the Ziehl-Neelsen method. We explained to subjects that this study was not a test of clinical knowledge or diagnostic ability but of the ability to assess normal and abnormal features in clinical photographs.

Defective colour vision was diagnosed using the Ishihara test (fail criterion of more than three errors) and severity was assessed using two or more of the following tests: City University, Farnsworth D15, Farnsworth-Munsell 100 Hue, Nagel Anomaloscope, Pickford Anomaloscope and American Optical Co HRR. As testing for colour vision was done throughout the UK, it needed the co-operation of several schools of optometry. As a result, the tests for assessment varied, however, the grading into mild, moderate and severe was done according to the advice of Birch.[9] More details of the assessment of colour vision are given in earlier papers.[5-7]

ANALYSIS

The performance of medical practitioners in defining areas of abnormality at each pixel of the electronic image of the photograph was compared within and between groups of practitioners with normal colour vision and mild, moderate or severe CCVD. The corners of the photographs were marked on the acetate to enable spatial registration of the outlines drawn by the subjects. The acetates were digitised by representing each outline as a polygon computed using map analysis software.[10] From the polygon representations, binary raster representations with three millimetre square pixels were computed using software written for this purpose. In these raster representations, a pixel is assigned the value 1 if its centre lies within the subject's marked outline, and zero otherwise. For each photograph, statistical testing was used to detect any difference between the outlines produced by different subgroups of subjects. A difference was detected if there was a significant difference in the frequency of marking at any single pixel. The testing at each pixel was by means of Fisher's exact test (thus avoiding the inaccuracies of the chi-squared test that occur with small samples). Testing was carried out only at pixels with sufficient numbers, which for Fisher's exact test means that the expected value in each cell of the associated contingency table was at least one. Even though sufficient statistics were available at less than 10 per cent of the pixels in each image, a large enough number of tests was carried out to require Bonferroni's correction (exact form) to prevent type I errors. In calculating the correction, the total number of tests in the entire analysis was taken into account, which includes testing at different pixels, of different photographs and between different subgroups of subjects. To achieve an overall conclusion confidence of 95 per cent, individual pixel tests were performed at around the 99.9995 per cent level of significance.

Initially, a four-way test between controls, mild, moderate and severe CCVD subjects was applied. This was followed by two three-way comparisons:

1. controls, mild and moderate CCVD subjects
2. mild, moderate and severe CCVD subjects.

Finally, a two-way comparison between controls and severe CCVD subjects was applied.

RESULTS

Of the 22 subjects with CCVD, five were mild, five moderate and 12 severe; 15 were deutans and seven protans. Figure 1 shows 10 photographs with names of the abnormality depicted. Accompanying nine of these photographs (a skin rash, stool and vomit) are the superimposed outlines by the groups of colour vision normal and CCVD practitioners. It should be noted that the complete failures to draw an outline cannot be detected by examining the superimposed outlines. The number of failures to draw outlines by subjects was 28 for stools, four for vomit and four for rash. For controls, the failures were three for stools, none for vomit and one for rash. For the 10th photograph (stained bacilli) in Figure 1, examples are shown of the bacilli marked by one subject and one control.

Figure 2 shows the digitised results. In a four-way comparison among controls and the three severity sub-groups of subjects, significant differences were found for the outlines of six of the nine photographs of physical signs (without blood present in one of stool and one of vomit). In neither of the two three-way comparisons (control/mild/moderate groups and mild/moderate/severe groups) was a significant difference found. In the two-way comparison between control and severe groups, significant differences were found for the outlines of two of the nine photographs. The two photographs, which were among the six identified in the four-way comparison, were both of stool with blood present.

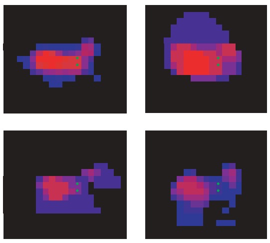
CCVD practitioners, as a group, differed from controls in the average number of bacilli identified in Ziehl-Neelsen stained sputum (Table 1).

Examining the electronic image of this photograph revealed that practitioners with CCVD had not only identified smaller numbers of bacilli in the photograph but had identified differing sub-populations (that is, in separate clumps) of the bacilli present.

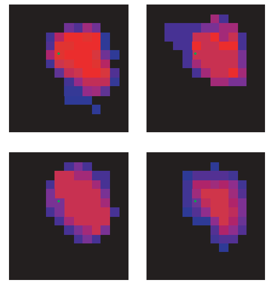
DISCUSSION

In this study, medical practitioners with severe CCVD (subjects) differed from those with normal colour vision (controls) in their ability to draw an outline of areas of abnormality in clinical photographs. They differed in three ways: failing to outline a part of a sign, failing to outline any of a sign and outlining an area where there was no sign.

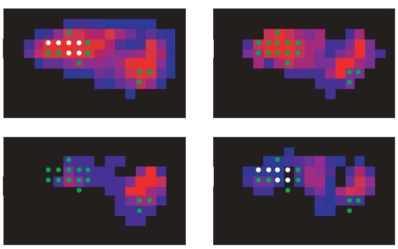
If the superimposed outlines (Figure 1) are examined alongside the corresponding photograph by direct visual inspection, it can be seen how the cues of dark/light (brightness) contrast, highlights, and variegated backgrounds, as well as the redness of the blood, have influenced the outlines. Controls are guided very largely by colour, whereas subjects are often guided by cues and not by the colour. In photographs 5, 6 and 8, there is little or no brightness contrast and it can be seen by the shape of the drawn outlines that highlights have been



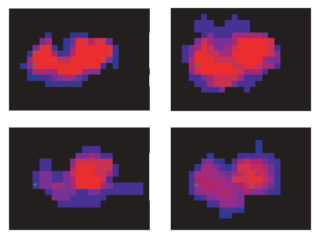
Photograph 1. Early erythema nodosum



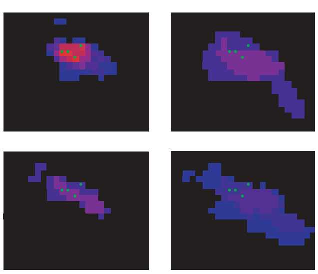
Photograph 2. Vomit with fresh blood



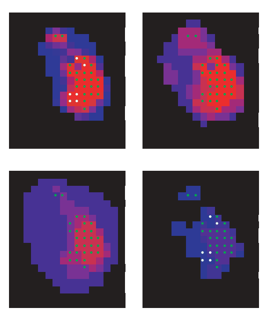
Photograph 3. Stool with fresh blood



Photograph 4. Vomit with fresh blood



Photograph 5. Stool and iron therapy with fresh blood



Photograph 6. Stool with fresh blood

Figure 2. The six digitised results of the outlines of clinical signs in the six photographs for which there were significant differences. Panels show the outlines by the subjects with CCVD and of controls with normal colour vision, (reading left-to-right and top-to-bottom: controls, mild, moderate and severe). These panels are centred on areas of abnormality in the photograph and use a colour code to show how often a pixel was marked as abnormal: black never marked, and blue through to red showing marking rates of one subject through to all subjects (in that group). Green and white dots mark locations where a significant difference existed between four groups of subjects (controls, and subjects with mild, moderate or severe CCVD). White dots highlight areas of the photograph where significant differences existed, when comparing responses of controls with medical practitioners having severe CCVD. Photographs 3 and 6 are those for which a significant difference was found when comparing the performance of physicians with severe CCVD and controls.

used by subjects as cues to the presence of blood. The highlights reflect light not only from the area of blood but also from moist areas of the normal sample and not from all areas of blood. This results in failure to outline all or part of the sign and causes areas outside the sign to be outlined as blood. In photograph 7, there was no fresh blood but here also areas with highlights were outlined. In photograph 3, there was a lack of brightness contrast in some areas of blood on the stool and there is failure to outline it by some subjects in these areas. In photographs 2 and 4 the darkness of the blood made it a cue to the correct outlines but variegated patterning probably caused difficulty. In photograph 9 (vomit with no blood), a few subjects outlined dark areas whereas controls outlined light areas. In photograph 1, there is little brightness contrast and highlights do not coincide with the abnormal pink area, so that some subjects failed to draw outlines and some outlined slightly dark normal areas. In photograph 10, the rod shaped pink bacilli are darker than their background, so that the subjects may well have been helped to detect them in this way.

We have reported previously on the reduced ability of medical practitioners with CCVD to report abnormalities in clinical photographs.[5,6] The results presented here add to that work by using a novel method of statistical analysis to define the probability of any area of a clinical photograph being reported as abnormal by subjects.

Differences were observed between subjects and controls following inspection of clinical photographs of vomit, stool, a red rash and a slide of stained bacilli. The results presented provide further evidence of the problems that may be encountered by physicians with CCVD in clinical practice and confirm the findings of Reiss and associates[11] concerning the recognition of blood in body fluids. For example, rectal bleeding is a common symptom—one study[12] identified a lifetime prevalence of 287 among 1,200 adult questionnaire respondents. Rectal bleeding is also an important component of models predicting the risk of colorectal carcinoma.[13] This is a disease with 24,000 new cases and 19,000 deaths each year in England and Wales.[14]

Group	Number	Bacilli (SD)	Significance
Control	17	37.2 (± 13.3)	
CCVD (all)	22	22.3 (± 8.4)	($t = -4.8$, $p < 0.001$)
Mild	5	26.6 (± 4.6)	
Moderate	5	14.4 (± 11.5)	
Severe	12	23.6 (± 6.5)	($F = 3.8$, df 2, $p < 0.05$)

Table1. Number of bacilli identified in sputum

Blood in vomit is also an important sign often indicating bleeding from the gastro-intestinal tract and sometimes requiring urgent action, particularly when it is fresh blood. In this study, practitioners with CCVD, especially those with more severe deficiencies, differed from controls in their ability to draw an outline of areas of blood in stool and vomit, either by failing to draw one or drawing it incorrectly. They made similar errors in outlining the pink rash.

Practitioners with CCVD identified fewer bacilli than controls in a photograph of Ziehl-Neelsen stained sputum. Small and rather inconsistent differences existed between the three groups of physicians with varying degrees of severity of CCVD in the number of bacilli identified. Others have documented the difficulties of medical and non-medical laboratory staff with CCVD in the assessment of histopathological slides and noted a trend towards those with more severe deficiencies making more mistakes.[14,15]

Not all medical practitioners with CCVD are aware of their problem.[2,3,15] There are no widely accepted policies in university medical schools for screening and advising medical students for CCVD. The evidence presented adds further weight to our earlier suggestions[5-7] that all practitioners and medical students should be aware of their status in relation to colour vision and that those with CCVD should undertake further testing to alert them to the severity and form of their condition. Practitioners with CCVD, especially when it is relatively severe, should take special care to ensure safe clinical practice.

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