- 34 Strawbridge WJ, Camacho TC, Cohen RD, Kaplan GA. Gender differences in factors associated with change in physical functioning in old age: a 6 year longitudinal study. *Gerontologist* 1993;33:603-9.
- 35 Palmore EB. Predictors of function among the old-old: a 10-year follow-up. *J Gerontol* 1985;40:244-50.
- 36 Harris T, Kovar M, Suzman R, Kleinman JC, Feldman JJ. Longitudinal study of physical ability in the oldest-old. *Am J Public Health* 1989;79:698-702.
- 37 Kuh D, Ben-Shlomo Y, eds. *A life course approach to chronic disease epidemiology*. Oxford: Oxford Medical Publications, 1997.
- 38 Spitzer R, Kroenke K, Linze M, Hahn SR, Williams JBW, DeGruy FV III, et al. Health related quality of life in primary care patients with mental disorders: results from the PRIME-ME 1000 study. *JAMA* 1995;274:1511-7.
- 39 Gliklich RE, Hilinski JM. Longitudinal sensitivity of generic and specific health measures in chronic sinusitis. *Qual Lif Res* 1995;4:27-32.
- 40 Katz JN, Larson MG, Phillips CB, Fossel AH, Liang MH. Comparative measurement of sensitivity of short and longer health status instruments. *Med Care* 1992;30:917-25.
- 41 Lydick E, Epstein RS. Interpretations of quality of life changes. *Quality of Life Research* 1993;2:2216.
- 42 Rose G. Sick individuals and sick populations. *Int J Epidemiol* 1985;14:32-8.
- 43 Cohen J. *Statistical power analysis for the behavioural sciences*. New York: Academic Press, 1977.
- 44 Ettinger WH, Fried LP, Harris T, Shemanski L, Schulz R, Robbins L. Self-reported causes of physical disability in older people: the cardiovascular health study. CHS Collaborative Research Group. *J Am Geriatr Soc* 1994;41:1035-44.
- 45 Barsky AJ. The paradox of health. *N Engl J Med* 1988;318:414-8.

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Deficient colour vision and interpretation of histopathology slides: cross sectional study

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Abstract

Objective: To determine whether histopathologists with deficient colour vision make more errors in slide interpretation than those with normal colour vision.

Design: Examination of projected transparencies of histopathological slides under standardised conditions by subjects whose colour discriminating ability was accurately assessed.

Setting: Departments of histopathology in 45 hospitals in the United Kingdom.

Subjects: 270 male histopathologists and medical laboratory scientific officers.

Main outcome measures: Number of slides correctly identified by subjects whose colour vision was measured on the Ishihara, City University, and Farnsworth-Munsell 100 hue tests.

Results: Mean (SD) scores (out of 10) for doctors with colour deficient vision were 9.4 (0.7) v 9.9 (0.4) for controls ($P < 0.01$) and 7.5 (1.6) v 9.4 (0.7) for scientific officers ($P < 0.001$). When subjects with colour deficient vision were categorised into severe, moderate, or mild, there was a significant trend towards those with severe deficiency making more mistakes ($P < 0.001$).

Conclusions: Histopathologists and medical laboratory scientific officers should have their colour vision tested; if they are found to have a severe protan or deutan deficiency, they should be advised to adopt a safe system of working.

Introduction

Histopathologists use a variety of coloured stains as an aid to diagnosis. In some cases the additional information provided by colour is superfluous and a diagnosis can be made by pattern recognition in a clinical context. Many of the stains use combinations of pigments which may be difficult for people with congenital red-green colour deficiency (dyschromatopsia) to distinguish, and there is evidence that doctors with colour deficient vision have problems with histopathological diagnoses.¹⁻³ There are also anecdotal

accounts of trainee histopathologists leaving the specialty because of difficulties with colour recognition.

If accurate colour discrimination is relevant to the diagnostic process it is important to guide doctors with colour deficient vision in the use, or avoidance, of particular stains and techniques that might cause difficulty. Normal colour vision may also be important to medical laboratory scientific officers who prepare histological specimens for diagnosis. As the prevalence of congenital red-green colour deficiency is much greater in males (8%) than in females (0.5%), we compared the performance of male histopathologists and medical laboratory scientific officers who had colour deficient vision with that of their colleagues who had normal colour vision in answering questions about stained histopathological slides.

Methods

A total of 270 male histopathologists and medical laboratory scientific officers in 45 hospitals across the United Kingdom took part in the study. Letters and a protocol were sent to the heads of departments of histopathology explaining the project and asking for volunteers who had spent more than a year in histopathology to take part. Subjects were asked by DH to answer questions on 20 projected (Kindermann) 35 mm transparencies of histopathological slides. The slides were chosen because people with colour deficient vision might confuse the colours in the stains. Transparencies of specific features taken from slides rather than the slides themselves were used so as to standardise the process of observation and ensure that each subject had the opportunity of seeing the same features.

The slides (see table) were in pairs and consisted of a true and false answer. Each correctly identified slide was worth half a mark, and subjects were marked out of 10.

After subjects answered questions about the transparencies, an optometrist (DJH) assessed their colour vision using the 38 plate, 1989 edition of the Ishihara plates; the City University test, second edition;

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Performance of 28 doctors and medical laboratory scientific officers in distinguishing pairs of slides

Description of slide pairs	No of mistakes
Lung tissue stained with Ziehl-Neelson; one showed <i>Mycobacterium tuberculosis</i>	7
Renal and cerebral tissue stained with Congo red and photographed part polarised; only cerebral tissue showed apple-green birefringence	5
Compound naevus, one stained with S100 and one with background stained with haematoxylin only	4
Small intestine: one stained with van Geison only and the other with Alcian blue/van Geison to reveal goblet cells	3
Fetal lung stained with Papanicolaou; one slide contained aspirated squames	5
Intraepithelial malignant melanoma stained with periodic acid Schiff (red) and Schmorl's (blue); the Schmorl's stained positively	11
Lymphoma stained with horseradish peroxidase/diamino benzidine; one slide had positive cells	1
Gastric antrum stained with haematoxylin and eosin; one slide contained <i>Helicobacter pylori</i>	2
Lymph node stained with Unna-Pappenheim; one slide stained more strongly positive than the other	6
Leiomyoma stained with van Geison and Masson trichrome; one slide strongly positive for smooth muscle	0*

*Staining problems; all subjects scored as correct.

and the Farnsworth-Munsell 100 hue test. The tests were illuminated with the MacBeth Easel lamp (standard source C) to give 350 lux (100 candelas/m²). Subjects with colour deficient vision were classified as either protan (abnormal long wavelength; red sensitivity) or deutan (abnormal middle wavelength; green sensitivity), using the Ishihara plates. The City University test confirmed protan/deutan classification when errors were made and detected tritan (abnormal short wavelength; blue sensitivity) colour deficiency. It was also used to grade the severity of red-green colour deficiency as slight, moderate, or severe. Subjects who failed the Ishihara test but made no errors with the City University test were graded as having slight colour deficiency, those with up to four errors as moderate, and those with five or more errors as severe. The Farnsworth-Munsell 100 hue error score, combined with an axis of confusion, was used to describe the severity of the practical hue discrimination deficit.⁴ Scores and colour vision assessments were strictly confidential to the subject and DH.

The statistical tests used were two tailed Mann-Whitney U, Kruskal-Wallis ANOVA (SPSS version 6.1.3), and the Jonckheere test (a non-parametric test of trend).⁵ All subjects signed a consent form, and ethical approval for the project was obtained from the research ethics committee of Dudley Health.

Results

Among 132 doctors, 15 (13%) had colour deficient vision (14 deutan, 1 protan); among 138 medical laboratory scientific officers, 13 (10%) were colour deficient (11 deutan, 1 protan, 1 tritan). Their job titles were professor (1), consultant (12), lecturer/registrar (2), senior medical laboratory scientific officer (7), and medical laboratory scientific officer (6). The mean length of time in histopathology was 16.9 (SD 8.8) years for subjects with colour deficient vision and 17.0 (9.5) years for subjects with normal vision. Three departments of histopathology and 18 doctors or scientific officers declined to take part after the project was explained. An unknown number of potential subjects were not available for personal reasons (annual leave, pressure of work, etc) at the time that DH visited their place of work.

Mean (SD) score of subjects with normal colour vision was 9.6 (0.6) and of those with colour deficiency was 8.6 (1.6) ($P < 0.0001$) (figure). Doctors with colour deficient vision were significantly poorer at identifying the slides than doctors with normal vision (mean score 9.4 (0.7) *v* 9.9 (0.4); $P < 0.01$); the same applied among scientific officers (7.5 (1.6) *v* 9.4 (0.7); $P < 0.0001$).

Two of the 27 subjects with red-green colour deficiency had severe protan defects and the remaining 25 had deutan defects. Colour deficiency was graded as slight in 11, moderate in 7, and severe in 9 subjects (excluding 1 with tritan defects). Seven of the scientific officers and two of the doctors had defects classified as severe. The one subject with a severe tritan defect had a prominent axis of confusion and error score of 220 on the Farnsworth-Munsell 100 hue test but made no mistakes in slide interpretation. Mean (SD) scores on slide identification were 9.6 (0.7), 8.6 (1.3), and 7.1 (1.5) for subjects with slight, moderate, and severe red-green colour deficiency respectively ($Z = -3.84$, $P < 0.001$ test of trend; $P < 0.001$ between the three groups). The mean (SD) Farnsworth-Munsell 100 hue error scores were 76.7 (18.6) for subjects with slight colour deficiency (none with an axis of confusion), 159.4 (34.6) for those with moderate colour deficiency (5 with an axis of confusion), and 202.2 (82.0) for those with severe colour deficiency (all with axes of confusion) ($Z = 4.36$, $P < 0.001$ test of trend; $P < 0.001$ between the three groups).

Discussion

Doctors and medical laboratory scientific officers with colour deficient vision made more errors in slide identification than subjects with normal colour vision. Furthermore, severity of colour deficiency was associated with the number of mistakes: subjects with a severe red-green colour deficiency made more mistakes than those with a moderate deficiency, who in turn made more mistakes than those with only a slight deficiency.

Diagnosis is not normally made from a single stained transparency, and histopathologists should

Scores of doctors and medical laboratory scientific officers (MLSOs) in discriminating 10 pairs of slides. Boxes show middle 50% of data; dotted lines indicate median values; bars indicate range other than outliers; circles indicate outlying data; asterisks indicate extreme values

have more clinical information available to them than was provided in this study. However, mistakes made by the subjects with colour deficient vision—such as missing mycobacteria, amyloid, or *Helicobacter pylori*—are clinically important and indicate that these subjects are disadvantaged in their work. Because mistakes were made with most of the slides and therefore with a large range of stains, it is difficult to advise histopathologists with colour deficient vision on the best stains to use. It is likely that histopathologists with this disability adapt their practice to find a safe system of working, but they may not appreciate the full range of hues that they are not seeing. This study did not test whether immunofluorescent stains which contrast light green or yellow against a dark green or black background are misinterpreted by someone with a deutan deficiency. Mistaken diagnoses would seem to be more likely if a colour deficient doctor and colour deficient scientific officer work together.

In the general population, deutan colour deficiency is three times more prevalent than protan deficiency; however, in this study the ratio was greater than 10:1. People with protan deficiency may self select themselves out of histopathology, or they may have been underrepresented in this sample. They have particular difficulty with red-black colour discrimination and would be expected to have the most difficulty with a study of this kind. Deutan deficiency too was greater in this sample than in general (9.3% v 6%), but the reason is unknown.

As recently as 1991, an editorial in the *Lancet* confidently stated that “the colour perception of the person peering down a microscope at a biopsy specimen is an irrelevance.”⁶ The results of this study challenge this view, and we recommend that the colour vision of all histopathologists and MLSOs is assessed. If they are found to have a severe protan or deutan deficiency, they should be counselled and advised to adopt a safe system of working. This might include avoiding specific staining techniques or using adaptive computer technology. This technology (which currently costs about £10 000) involves electronically capturing the polychromatic image of the slide under the micro-

Key messages

- Coloured images are being used increasingly as an aid to diagnosis, but 8% of men and 0.5% of women have colour deficient vision
- Histopathologists and medical laboratory scientific officers who stain histopathological specimens should have their colour vision tested; if they are found to have a severe protan (red) or deutan (green) deficiency, they should be advised to adopt a safe system of working
- Students at medical school should have their colour vision tested as this may help with their choice of specialty and alert them to potential difficulties with their work

scope, changing it into digital form, and then converting with specialised software the red, green, or blue parts of the image into colours which the histopathologist can identify.

Ideally, histopathologists should have their colour vision tested before entering the specialty. Doctors with colour deficient vision have suggested that students should have their colour vision tested at medical school as those with dyschromatopsia may have problems with endoscopy, fundoscopy, polychromatic radiological imaging, and colorimetric blood or urine testing.^{7,8}

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- 1 Vorster BJ, Milner LV. Colour-blind laboratory technologists. *Lancet* 1979;ii:1295.
- 2 Rigby HS, Warren BF, Diamond J, Carter C, Bradfield JWB. Colour perception in pathologists: the Farnsworth-Munsell 100 hue test. *J Clin Pathol* 1991;44:745-8.
- 3 Bogman MJ. Colour blindness and pathologists. *Lancet* 1992;339:185.
- 4 Birch J. *Diagnosis of defective colour vision*. Oxford: Oxford University Press, 1993.
- 5 Leach C. *Introduction to statistics. A non-parametric approach for the social sciences*. Chichester: Wiley, 1979.
- 6 Colour prejudice among pathologists [editorial]. *Lancet* 1991;338:1302-3.
- 7 Spalding JAB. The doctor with an inherited defect of colour vision: effect on clinical skills. *Br J Gen Pract* 1993;43:32-3.
- 8 Currier RD. A two and a half colour rainbow. *Arch Neurol* 1994;51:1090-2. (Accepted 1 August 1997)

Prevalence of HIV-1 infection among heterosexual men and women attending genitourinary clinics in Scotland: unlinked anonymous testing

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In late 1990 a survey of unlinked anonymous HIV testing of patients attending genitourinary clinics in Glasgow and Edinburgh was implemented to monitor the prevalence of HIV-1 infection among sentinel populations at high risk of infection. These clinics served 90% and 100% of their respective city populations. We report on the prevalence of HIV infection among heterosexual men and women who were not known to have injected drugs and who attended clinics in Edinburgh and Glasgow from 1991 to 1995.

Subjects, methods, and results

Each clinic routinely performed serology testing for syphilis on patients who might have acquired a sexually transmitted disease. Patients eligible for study included those who presented for the first time in a calendar quarter and who did not object to their blood undergoing unlinked anonymous testing for HIV. Epidemiological data were recorded and included clinic of attendance, sexual orientation, sex, whether the patient

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