COLOUR VISION TESTING:
SCIENCE OR JUST BAD HABITS?

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INTRODUCTION
The testing of colour vision in aviation has always been a controversial area, lacking standardisation across various jurisdictions. Currently in Australia, all applicants for medical certificates are tested for visual acuity and colour vision at their initial examination. An ophthalmic examination is also performed for Class 1 and 3 applicants. While visual acuity is retested at each examination, no further eye exam is undertaken until age 60. In addition, unless the certificate is allowed to lapse, no further colour testing is undertaken. This is not logical because it represents an ad-hoc test for a small number of applicants, and is not connected with any medical condition; nor does it reflect any change of medical status.

Initial testing of colour vision is performed using Ishihara plates, first developed by Shinobu Ishihara in 1917. This is an excellent test for red/green colour-blindness, but with limited application outside this spectrum. There are also a number of well-known limitations to these plates based on lighting conditions, fading of plates, and the possibilities for cheating.

COLOUR VISION CONDITIONS
Congenital colour blindness is present from birth in about 10% of the population. It is an X-linked condition, most common in the Caucasian and Asian populations, affecting males 8:1. It is a stable condition that doesn’t change through life, and mostly affects red/green discrimination, with varying severity.

Acquired colour deficiency develops later in life, usually as a result of disease processes with varying severity and rates of progress. A number of common conditions can affect colour vision, including glaucoma, multiple sclerosis, macular degeneration, retinal detachment and diabetes.

Glaucoma is a condition causing increased pressure within the eyeball, which results in damage to the retina and optic nerves. It is capable of causing significant damage before causing clinical symptoms. Colour perception changes have been noted in glaucoma since the late 19th century and have been recognised to be present before any visual field defects could be detected. However, a number of technological developments of the last few decades have enabled detailed measurements of the retinal nerve fibre thickness, retinal topography and electroretinograms, among others, which have allowed us to quantify the deterioration with eye conditions.

ABOUT THE AUTHOR
Dr David Collis graduated from University of Adelaide in 1986, working in various registrar positions for a number of years before commencing at his current practice at St Andrews Medical Group in Midland, WA, where he has worked for the last 21 years as a general practitioner with interests in minor surgery and skin cancers. He has been a DAME for 14 years, since completing the Monash ACCAM course in 2001.

Dr David Collis was awarded the Jeanette Linn Award for the Best Presentation by a first-time presenter at the 2015 ASAM Annual Scientific Meeting, for his review of colour vision testing in aviation. This paper is based on the original presentation delivered at the 2015 Annual Scientific Meeting of the Australasian Society of Aerospace Medicine.

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ABSTRACT
Colour vision testing has been and remains a controversial subject in aviation. Despite this, colour testing methods have remained essentially unchanged in many years. This presentation reviews the relevance of colour testing methodologies to modern aviation and presents a review of recent literature relating to colour vision and how it is affected by various physiological states and changes occurring with various pathological conditions; and the relevance of these discoveries to current and future aeromedical certification processes.

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In glaucoma, the colour deficiencies found early can be shown to correlate with areas of later field defects, and that deterioration in colour vision correlates with measured thinning of retinal nerve fibres and changes in retinal topography as the condition progresses.

Similar findings have been made in multiple sclerosis, a condition in which colour vision abnormalities have also been recognised for a similar period. Work in this area has also established that colour vision changes occur early in the condition, preceding changes in VERs and ERGs. As in glaucoma, these changes can also be correlated with changes in the retina as the condition progresses. Interestingly, colour vision changes were found to be present independent of optic neuritis. This therefore may have some predictive value.

However some cautions apply to these findings. Although predominantly affecting blue colours, no particular part of the colour spectrum stands out. A number of different testing procedures were used, thus there is no standardisation of the results. Also, many of the results have been variable, and the small size of many of the studies could limit their wider application.

In macular degeneration, the breakdown of normal retinal function interferes with nutrition of the retina and removal of waste products, leading to accumulation of debris in the retina and consequent deterioration of vision. Some studies have noted changes in perception of colour early in this condition, again showing a predominantly tritan (blue) effect. This is not however found in all cases. As the condition progresses, the fluid accumulation which occurs in the macular region results in visual distortions and central field loss.

This condition is also associated with problems with decreased sensitivity, causing problems in low light conditions, night vision and other low contrast environments.

Retinal detachments are caused by fluid leaking between the layers of the retina, usually through a tear. This results in a visual field defect in the detached area, but also causes damage to the cones in the affected area. The degree of damage is directly related to the length of time that the retina is detached, so the sooner it is corrected, the better the outcome. Visual acuity and colour perception will improve in time, however full return to normal vision is not guaranteed. The blue receptors bear the brunt of damage in this condition, so blue and yellow colour distortions are the most common.

Vision changes in diabetes result from the effects of high sugar levels. Firstly, high sugar causes cloudiness of the lens of the eye, reducing the amount of light reaching the retina (luminance reduction). This is also associated with a yellow filtering effect, thus reducing the amount of blue light reaching the retina. Secondly, the toxic effects of sugar in the retina in retinopathy cause damage through a variety of mechanisms, one of which is toxicity to the cones. Various authors have reported changes in blue colour discrimination in diabetics, while other researchers have found changes across the spectrum. There is no clear
consensus as to whether colour effects are due to transmission reductions or perceptual reductions, and no clear link has been established between duration of illness, HbA1c levels, fasting BSls and colour deficiencies. Studies are also confounded by the variabilities found between diabetic patients.

The ‘miscellaneous’ category includes phenomena of colour change reported with medications, (the best known are Viagra, Digoxin and Chloroquine) which are due to effects on the function of the retina itself. Occupational exposures can also cause changes in colour vision, as described by Guest in 2011 in a study of RAAF maintenance workers exposed to vapours while servicing the fuel tanks in F-111 fighter/bombers.

Serous central retinopathy is another condition that is reported from time to time. This is another condition where oedema and fluid leakage develops in the macula region without retinal separation. This causes a temporary loss of visual acuity and colour perception, but clears in most cases back to normal in around six months. It may occasionally recur, and a small percentage may develop a chronic condition.

In Alzheimer’s disease there have been reports of similar effects on colour vision in as in Multiple sclerosis, due to retinal thinning measured by OCT changes. However, reliable results can obviously be more challenging to obtain in this population due to issues with some test performance, and to date, no reliable correlation appears to have been developed. The majority of studies have also been undertaken in subjects already diagnosed with Alzheimers, so any predictive value is zero. As this is a condition usually in the older age groups, the aeromedical impact is likely to be low, although if predicted trends for dementia in the aging population prove true, this could become a bigger problem in the future.

The blue (S, short-wavelength) cones appear to be the most vulnerable to damage from ischaemia and pathology of the retina. This is due to differences in the structure and function in these cones compared to the green and red cones, as well as to differences in carbonic anhydrase activity in each type of cone. Blue cones don’t contain this enzyme and are reliant on the other layers of the retina for it, making them more liable to damage and death when separation occurs.

Measurements of colour have been undertaken with a variety of instruments, however no consistent testing methodology across the scientific literature. Apart from pseudoisochromatic plates, none of the other test methods are suitable for routine use in a consulting room. This includes the increasing use of computer based assessment tools, thanks to the improvements in monitor technology in recent years.

So in summary, colour perception abnormalities are associated with a congenital defect as well as a range of clinical conditions, with a tendency for blue and yellow perception to be affected by acquired colour deficiencies. However, results across a number of studies do not appear to provide a consistent and clear pattern to these changes.

We should also note that visual acuity changes frequently occur in all of these conditions, along with other manifestations of the disease progress, and from a certification point of view, acuity is far more likely to affect the holding of a medical certificate than colour changes.

CLINICAL APPLICATION OF COLOUR VISION TESTING

Whatever testing procedure is used is likely to be complex. It needs to target blue colour changes, and will probably not be an iso-chromatic plate series, particularly the Ishihara charts. At the present point, the most conclusive evidence points to the potential use of colour vision screening in the detection of glaucoma and multiple sclerosis.

There is no sound clinical evidence for re-testing lapsed certificate holders with Ishihara charts. Re-testing with the Ishihara plates yields no new useful information, and can be discarded without undermining flight safety.

But this also raises a more fundamental question of how vision is tested. Visual acuity testing, as currently practiced, is a high contrast test, performed most often with the Snellen chart, which was first designed by Herman Snellen in 1862. Performed in daylight or equivalent, it is a quick and reliable test of visual acuity. The aviation environment, however, frequently requires discrimination of objects in a variable contrast environment, therefore some form of testing needs to address the pilot’s abilities in this area also.

DISCUSSION

The use of colour in aviation has come a long way from the early days of basic instruments, with EFIS displays now being widely available, able to be altered to numerous colour palettes.

However, there are still significant issues related to the use of blue lights in aviation, such as approach and taxiway lighting, which in many countries is a mix of yellowy-greens and blue edge lighting. Could this be a potential source for problems at night with someone with moderate (if treated) glaucoma?

We should also bear in mind that colour is not the only visual clue in use when flying. Ishihara charts will still have a place for screening for congenital colour blindness, but I don’t believe they have any significant role in testing for acquired colour vision problems. Visual acuity changes and other effects of the disease process remain far more likely to affect a pilot’s airworthiness than the changes in colour vision described in this presentation. Current testing standards are a hotchpotch, but this situation will only change with a combined global regulatory approach.
REFERENCES


