Standards for defects in colour vision psychology essay

Abstract

Introduction

Colour vision standards have been an important factor in many occupations in New Zealand and overseas. Standards for defects in colour vision has been imposed for various reasons, but the need for the standards has been questioned, especially by the individuals who lack perfect colour vision, and are barred to enter the occupation of their choice [1, 2]. There are various tests that are performed to detect and quantify the colour vision deficiency but they cannot reliably conclude if a person with colour vision defect can perform the task efficiently and without risk [3, 4]. The occupational colour vision standards for New Zealand manual was last updated in 1992 [5]. Since then, a lot of changes have been made in the colour vision standards for various occupations in New Zealand. It is essential to update the colour vision standards so that the Optometrists in this country are well educated to give informative advice to their patients about their career choice.

Case One

A 14 year old Caucasian male was referred by his optometrist to the University of Auckland Optometry Clinic for a full colour vision assessment. He is a student and wants to pursue a career in the New Zealand Army. There is no family history of colour vision defect. He reported noticing colour vision defects when he was in are intermediate school and the defect is equal in both eyes, and has not changed over the years.

His unaided vision was R 6/6 and L 6/6. Binocular vision and accommodating systems were found to be in normal limits. Anterior and posterior ocular health examination was unremarkable.

He failed the Ishihara 24 plate edition test by having 14 errors on the 14 plates between 2 and 15. The results on Medmont C100 test were consistent with +2 indicating a deutan defect. He passed the Farnsworth Dichotomous Test (Panel D15) on a retest with one simple transposition. In the Lanthony's Desaturated D15 test he made two diametric crossings although the colour confusions made did not allow a judgement to whether the colour vision is protan or deutan. As the results of the Farnsworth Dichotomous Test (Panel 15) were a pass, then these results indicate that the defect is moderate in severity. Farnsworth Lantern Test (FALANT) was performed on him whereby he made seven errors in the first run followed by 12 errors in the next two trials therefore failed FALANT. Red was confused with green, green was confused with white, and white was confused with green and red. He is a moderate deuteranomal with a matching range in the Roland Anomaloscope from 0 to 50 scale units (red-green mixture value). He was advised that due to his moderate deuteranomal colour vision defect he would most likely have restrictions to certain profiles in the New Zealand Army (appendix).

Case Two

An 18 year old Caucasian male was referred by his optometrist to the University of Auckland Optometric Clinic for a full colour vision assessment to after failing the Ishihara screening test. He wanted to know whether he met the colour vision standard for New Zealand Police recruits. There is no family of colour vision defect and he first noticed getting confused between grass and rabbit. He admitted having difficulty reading in green and red and in unsure whether one or both of his eyes are affected.

His unaided vision was R 6/7. 6 and L 6/6. The optometrist did not report any abnormality of his anterior and posterior segment therefore it is assumed that it is unremarkable. On the Ishihara 24 plate edition test he had 10 errors out of the 14 plates and recognized numbers 2 and 4 on the diagnostic plate 16 and 17. Responses to the diagnostic plates indicated the likely type of colour vision defect as deutan however the diagnostic plates are not completely reliable. Upon testing with Medmont C100, a consistent result of +1 was obtained again which indicated a deutan defect. He passed the Farnsworth Dichotomous Test (Panel D15) with a simple transposition. The Lanthony's Desaturated D15 test results showed with a single transposition of the adjacent hues indicated that the colour vision defect present in him was likely to be mild; on the other hand no inferences about the type of any colour vision defect could be made from those results. He made four errors on the first run on the FALANT thus the results were discarded and two more runs were presented. He failed the FALANT as he made seven errors in the second and third runs. It was noticed that he confused white with green, red with white and green with white. Roland Anomaloscope was used to identify the severity of his colour vision defect and it showed a range from 12 to 15. 5 scale units (red-green mixture value), suggested a presence of mild deuteranomal. According to the New Zealand Police Recruitment Guidelines (appendix), the colour vision criterion was not met by him since he failed the FALANT despite being a mild deuteranomal.

Case Three

A 28 year old Caucasian male was referred by his general practitioner to the University of Auckland Optometry Clinic for a full colour vision assessment. He expressed an interest at applying for a Class 1 (commercial) CAA Medical Certificate. He has been aware of his colour vision deficiency since about seven years of age. His family history revealed his maternal grandfather also having a similar colour vision deficiency. From his knowledge, both of his eyes had similar lack of colour perception and had not changed over years.

His aided vision was R 6/6 and L 6/6 -2. Because of his unchanged and binocular colour vision deficiency, it was assumed that it was a congenital colour vision defect, and the anterior and posterior segment was unremarkable. He made 14 errors in the Ishihara 24 plate edition between plates 2 and 15; the diagnostic plated revealed the possibility of the deutan defect since he recognised numbers 2 and 4 in the diagnostic plates 16 and 17. A judgement to the severity of the colour vision defect could not be made on the basis of the Ishihara test. Medmont C100 gave a consistent result of +1 advocating a most likely deutan defect. Farnsworth Dichotomous Test (Panel D15) results showed six parallel diametric crossings in the deutan axis in the initial test, which changed to three parallel diametric crossings in the deutan axis in the retest. This suggested that the colour confusion he made was likely to be of a severe deutan type defect. A total of seven errors were made in the FALANT test on the first run, and 11 in the next two trials, which indicated he failed the test. He confused red with white, green with white, and white with green and red. Roland Anomaloscope was finally used to detect the severity of the deutan defect and it showed a range from 1 to 60 scale units (red-green mixture) which indicated severe deutanomaly. In the view of the results, it was certain that he was not eligible to become a commercial pilot but may well be issued with a Class 1 Civil Aviation Authority Medical Certificate but with restrictions and conditions.

Discussion

Colour vision deficiency affects approximately 8% of males and 0. 4% of females in a Caucasian society [1]. Prevalence of CVD in Asians and Africans are considerably as less as 2% [6]. Congenital colour vision deficiency has three categories: monochromats, dichromats and anomalous trichromats. Monochromats have total colour blindness and are associated with poor vision and they function with rods and one type of cones[6]. They are very rare with an incidence of 1: 1, 000, 00[1]. Dichromats have only 2 types of cones present therefore require two-colour primaries, namely green and blue to match the entire colour they are capable of perceiving. A protanope will have difficulty with red and blue/green and a deutranope with green and purple. Tritanope will have decreased perception along the blue-yellow axis. Anomalous trichromats have all three cones; however the peak luminous of one of them is shifted from its normal value [7]. An anomalous trichromat requires significantly greater saturation with the defective colour, as compared with normal observers. The commonest colour deficiencies (deuteranomalous and protanomalous) are X-linked which predominantly makes male a stable population of colour vision deficiency.

A small proportional of colour vision defects are acquired secondary to ocular diseases, drug side effects, or serious systemic disease such as diabetes, multiple sclerosis or HIV [6, 8]. An ocular disease such as glaucoma and diabetic retinopathy affects the blue mechanism whereas red-green deficiency occurs in optic nerve pathology [6, 8, 9]. The severity of the deficient colour perception changes with time. Therefore it is considered wise to do monocular colour vision testing in adults, and it is also vital to ask patients if they notice any change in colour perception over time.

Optometrists have a responsibility to check the colour vision status of all individuals because abnormal colour vision has practical consequences. An early knowledge of colour vision deficiency can help patients to make the right career choice and avoid disappointment. A survey conducted by Steward and Cole (1989) showed that 68% of the anomalous trichromats and nearly 90% of dichromats reported difficulties with everyday tasks including work that involve colours [10]. Forty nine percent of the dichromats and 18% of the anomalous trichromats admitted difficulty distinguishing the colour of traffic light signals [10]. Deutans can confuse reds and greens with amber, yellow and white, and protans see the red is seen as deficiency as brown, dark grey, or black. This could probably explain why protans have higher road accident rates than colour normals due to increase reaction time [11]. The study done by Dain et al (2009) looked at the effect of sunglasses on the recognition of signal lights of colour vision defect subjects [12]. It was proven that colour vision defective subjects had significantly longer response time than the normal colour vision subjects when looked through clear, gray, yellow-brown and red-brown lenses. The response time was worse when they looked through green and yellow-green lenses. Deutans performed worse than protons in this study. Therefore individuals who have colour vision deficiency should avoid using green and yellow-green lenses and be more cautious while driving[12]. The use of coloured filters is also prohibited in all pilots. Only neutral density gray lenses are recommended for all aviators due to the factors discussed above can impair colour vision and prohibit flying [6]. Another study done by Ramaswamy et al (2009) proved that colour deficient observers need 14% more to time to complete colour identification test than colour normals which can restrict a person from advancing in their career due to safety purposes [13].

It is not often easy to give advice to a patient about his CVD. Stewart and Cole [14] reported that of the 18 patients in their survey who were unaware of their colour vision abnormality, half expressed disbelief and objected having any difficulty, whilst the other half agreed on the problems they faced with colour. It is also difficult to give them definite career advice as various occupations have colour vision requirements and differ between countries, and between states in certain countries, and are often poorly defined and administered. Normal colour vision is required for recognition of signal lights and colour codes for safety purposes and these tasks forms the basis of the occupational colour vision standards, therefore deck officers and seamen, train drivers, air traffic controllers and people in some occupations within defence force need to have normal colour vision (appendix). People with mild defect are often not allowed to pursue their career in their chosen career path. There are also several occupations for which there is no statutory colour vision requirement but abnormal colour vision is a handicap. These include identifying and grading gems in the jewellery trade, cotton and wool graders, using colour coded maps as a geographer, meteorologist or demographer, and judging the freshness of a meat, electrician, medical practitioner, optometrist, dentist, pathologist, horticulturist and fruiterer [1, 15]. To avoid disappointments later in life, it has been suggested that colour vision screening should be done in school. This can help the children learn other cues to recognise different objects around them. Currently in New Zealand, all boys who are 11 years of age are screened for colour vision deficiency at school [16]. Sometimes regardless of knowing the type and severity of a person's colour vision defect, it is still difficult for a clinician to give advice to someone who has a colour vision deficiency because of the uncertainty of the practical problems one may face.

There is no single test that can provide an optometrist with all the information about a patient's colour vision status. It is often hard for a practice to decide which colour vision tests to purchase as there around 18 different pseudochromatic plate tests, eight kinds of scoring/arrangement tests, five anomaloscopes and five lantern tests [14]. The gold standard that was recommended by Birch to purchase was anomaloscope however due to its cost and the personnel being properly trained, an optometrist resists purchasing one [17]. The tests that have been recommended for the assessment of colour vision in primary care are Ishihara test, Medmont C100 test and Farnsworth D15 test [1]. Ishihara test is commonly used in most practices to detect protons and deutans. It is published in a full 38-plate edition, an abridged 24-plate edition and a 14-palte edition for a quick screening. Errors of three of more indicate red-green CVD with 2% chance of misdiagnosing normal colour vision [1]. Ishihara is found to have 97. 9% efficient[1], sensitivity[2]of 76. 9% and specificity[3]of 100% Plate number

16 and 17 help differentiate protons from deutans but the chances of error is 30-40% [1]. The advantage of Ishihara is that it is cheap, portable and can be easily run by anyone. [17]. The drawbacks of this test are that the number of errors does not indicate the severity of the defect and this test is not useful to detect a tritan defect. In addition to that, colours of the plates start to fade in course of time and it is necessary to achieve the right daylight illumination to get reliable results. This test is also widely available that those who wish to pass for occupation standards purposes can obtain a copy and learn the correct answers. The Medmont C100 test distinguishes protan from a deutan and it also has a high sensitivity and specificity [1]. This test is performed after one has failed Ishihara test. After five readings an average is taken for minus or plus reading, which determines protan or deutan respectively. Again, the magnitude of the reading cannot be used to judge the severity of one’s colour vision defect. One test that can categorise those with abnormal colour vision as either ‘ mild’ or ‘ moderate/severe’ is Farnsworth Dichotomous test (Panel D15). It may also discriminate protan, deutan and tritan defects. The test has good test-retest reliability for pass/fail with a coefficient of reliability of between 0. 96 and 1. 0 [1]. There is some ambiguity about the criterion for failing this test. Someone with a normal colour vision can also make error if the criterion is any error. Two or more diametrical crossing is regarded as the best criterion for fail [1]. It was thought those who pass the Farnsworth D15 test have a mild deficiency and would not be a disability in their everyday colour task however this is not true. There are a number of them who passed the test and can recognise colours of signal lights and surface colours, but studies have shown that there there are also a good number who cannot [1].

There are three types of lantern test designed for selection certain occupations. They are Farnsworth Lantern test (FALANT), Holmes-Wright A (H-W A) and B (H-W B). The H-W A displays vertically separated red, green and white signal lights in nine pairs of different combinations. There are two different shades of green and red [18]. One green has a blue-green colour, which is more likely to be confused with white by a protan observer, and the other green is slightly yellowish and is likely to be confused with white by a deutan observer. The two shades of red are orange red and deep red, and latter is used to depict railway signal and that increases the chances of a protan to make mistake. There are two settings for H-W A: high and low. The low setting is reserved for dark room with dark adaptation and it is equivalent to H-W B lantern which is used for maritime and industry [18]. H-W A has been approved the Joint Aviation Requirements (JAR) and is used to select commercial pilots in the UK and former Commonwealth Countries[19]. It is also recommended by the Commission Internationale d'Eclairage (CIE) to be used in a range of international transport services such as railway [20]. Lantern tests are adopted to select aircrew [19]. The UK CAA authority applies the JAR criteria to candidates for a class 1 Aviation medical certificate (CAA class 1). If a candidate passes the Ishihara plates, he/she is able to obtain CAA class 1 medical certificate. However, if an applicant is indicated to have red-green deficiency with the Ishihara plates, then further assessment with H-W A is required [19]. Holmes-Wright B is the strictest test that a small proportion of people with normal colour vision will fail it [17]. The Civil Aviation Authority (CAA) in New Zealand requires applicants to pass H-W A or FALANT to qualify for CAA Class 1, 2 and 3 Medical Certificate without restrictions (appendix). The person in Case 3 did not pass FALANT therefore he might be allowed to hold a CAA Class 1 and 2 Medical Certificate with restrictions and conditions.

Most occupations that involve high risk with colours require a person to have excellent colour vision. This is to solely reduce the risk of the person himself and the general public. As mentioned before pilots, firefighters, train drivers, defence force personnel and police officers need to have adequate colour vision to carry out their role safely. Major events have led to development of medical standards, including colour vision standards, such as in January 2003 where a passenger train travelling between Sydney and Port Kembla on the New South Wales south coast failed to slow down on a curve, killing the driver and six passengers [21]. The driver at that time suffered an incident of ventricular fibrillation. He had a pre-existing psychological impairment which could have led to the inadequate response to the emergency situation. Since then a project was undertaken to develop a standard for the Australian rail industry where all Railcorp train drivers and driver recruits were screened for medical fitness and tested with Ishihara plates to assess their colour vision. At least 4 recruits were found be unfit because of their colour vision impairment [21]. The National Transport Commission of Australia (guidelines are also followed in New Zealand) introduced a National Standard for Health Assessment of Raiway Safety Workers which stated that before recruiting, colour vision needs to be examined thoroughly. All applicants must be tested with Ishihara, Farnsworth D15, Medmont C100, FALANT or a practical test designed by the railway industry (appendix). Another train incident was in 1996 where two New Jersey Transit trains collided near Secaucus, New Jersey [20]. The National Transportation Safety Board (NTSB) concluded that the accident was due to one the engineer acquired colour vision deficiency secondary to diabetic retinopathy and the photocoagulation treatments, who failed to stop when the stop signal was given. The Federal Railroad Administration thereafter went changed the colour vision testing procedure and standards, and that specified an individual to pass at least one of the specified colour vision tests.

The history of military colour vision standards started from 1875 after the train crash in Sweden [22]. Colour vision standards for the US Navy and Army developed after the English translation of ‘ Colour Blindness in Its Relation to Accidents by Rail and Sea’ became available in 1877. At present Ishihara and FALANT are used to screen colour vision defects by the U. S Military. The FALANT was developed to recruit suitable ship drivers during the WWII and it on purposes passes approximately 30% of colour vision deficient individuals[22]. However, the Air Force no longer accepts the FALANT for the people who failed the Ishihara test. The Ishihara tests that were developed had never been validated against the aircrew task requirements. Recent studies have also found that a proportion of individuals who pass the FALANT are not able to identify some approach lighting which is safety critical [23]. It is still unsure whether FALANT and Ishihara tests and colour vision standards enhances the safety or usefulness of military aviation operations. A new test called Colour Assessment and Diagnosing test (CAD) has been developed that identifies congenital red and green deficiency and would allow nearly 35% of the people with colour vision deficiency to join aviation with the confidence that they can safely perform all the required duties of ground and in-flight civil aviation [22, 24]. However the CAD test might not be useful enough for the people who want to join The Airforce as the requirements for the Airforce and Civil Aviation is quite different. This raises an important point that military is likely to exclude potentially capable people. Referring back to Case 1, being a moderate deuteranomal is a disadvantage for him as he will be restricted from certain solider and officer profiles (appendix).

Colour is used extensively in aviation. It is used in the airfield, navigation lights, flight deck instruments panels, and for air traffic control applications [4]. It is also used for warning signals; therefore it was thought that colour deficient individuals would not be suitable for jobs in aviation. Apart from colours now, luminance contrast, object shape, size and location in the visual field are more often used to distinguish objects in aviation [8]. There is still a debate that the present requirements and testing an individual's ability to distinguish colours in their working environment are justified for the actual tasks that pilots do carry out in their job [8]. Farnsworth lantern test is used in New Zealand, Australia and United States Aviation, while Holmes Wright in used in European countries [21]. New Zealand Civil Aviation Authority requires an applicant to pass FALANT in order to obtain Class 1, 2 and 3 Medical Certificate with no restrictions (appendix).

Firefighters have to know certain colour codes for indentifying industrial gas cylinders, portable fire extinguishers, traffic signal and pipelines [9]. It addition to that, they can get useful information about the origins of the fire by the colour of the smoke and flames. However, gas cylinders have other non colour cues to differentiate between them such as the size, shape, protecting shroud and reflectance but dichromats are still bound to get confused between colour coded objects, therefore are unsuitable for work in the fire service. The present standard in Great Britain for firefighters is that they need to pass the Ishihara plates without making more than 2 errors to enter the fire services[9]. In contrary to that, there are no colour vision requirements for firefighters in New Zealand (appendix).

A study by Birch et al. (2008) showed that majority of the police officers admitted that colour recognition is important for effective policing and that everyone who wants to join the police force must undergo colour vision tests [7]. The Home Office guideline (2003) suggests that Farnsworth D15 is the recommended test but the test procedure and pass/fail criteria is not disclosed. People with slight colour vision deficiency tend to fail Ishihara but pass D15, and a circular result diagram is the optimal pass criterion, which includes a single transformation of adjacent hues [7]. A person should be given a second attempt to achieve a pass, and a test should be repeated should more than a single transformation of adjacent hues or a maximum of two lines crossing the results diagram is found. Dichromats and severe trichromats may not be suitable for specialist roles in Police and might have to be excluded from certain tasks that require colour coded instruments to be used such as a breathalyser. It was also found that protans take twice as long as other drivers to react to a red light therefore twice as many chances of accidents [7]. Applicants for New Zealand Police must pass FALANT test to be eligible to become a police officer (appendix).

Colour vision tests can be used to judge whether a person's colour vision deficiency would cause danger to himself or the general public, but so far, there has not been a single test that has ever reliably matched colour vision deficiency with the level of performance on specific in-flight tasks for example. Siu et al. (2003) did a study to see how well individuals with colour vision deficiencies perform specific colour tasks of the type typically found on the airfield, and to determine if the clinical tests routinely used to assess colour vision have high predictive value in terms of real-life task performance [4]. It showed that the Farnsworth lantern test had 100% and D15 had 87. 5% sensitivity for detecting colour defectives that were unable to pass the colour specific trade tests. This study shows that 66. 7% of colour defective populations as defined by the Ishihara can still recognise the colour tasks. They are considered competent to communicate adequately in the airfields, as far as colour signalling is concerned [4]. Protan subjects consistently failed the clinical and trade tests therefore strongly support the view that they should not be allowed to drive on the airfield. A trade test is the only test that can be compared with the real world encounter, and that should be used to see if people with colour vision defects can perform well or not [4]. The pilot who was a part of Federal Express Flight 1478 crash on 26 July 2006 was proved that passing lantern test is not enough and so did the study by Barry et al (2007), it investigated to see if the colour defective people who pass the lantern test are able to recognise the main colours used for surface colour codes in aviation systems [25]. Only 19% of the defective colour vision people passed the lantern test, and of that 74% made no errors with the surface colours. The subjects with normal colour vision made no errors with the surface colours [25]. Therefore, Farnsworth lantern test will ensure that those who pass have reasonable colour discriminating ability, however it is not saying that passing the Lantern test is enough since it does not simulate demanding conditions.

From the study that was done by Cole et al. (1983), it shows that colour vision tests such as D15, D15 Sat, H16, City University, FM100 and Nagel Anomaloscope are imperfect predictors of the result of a lantern test i. e. Farnsworth Lantern Tests, Holmes-Wright A and B Lantern Tests [26]. Therefore it's hard to give an advice to a patient whether he will pass or fail a lantern test based on the clinical assessment of colour vision. It is evident from this paper that lantern test cannot be replaced by any other colour vision tests since other tests do not hold the capacity to recognise small coloured stimuli [26]. Cole et al (2006) also found that about 20 to 30 percent of those with abnormal colour vision pass the Farnsworth Lantern test which is a requirement for aviation applicants in Australia and United States. Hovis et al. (2008) found that Ishihara failed 3. 7% of normal colour vision individuals who passed both the simulation and lantern test [20]. Cole and Maddocks found that a pass of Farnsworth Panel D15 Dichotomous test (less than two or more diametrical crossing) has a sensitivity[4]of 0. 67 and specificity[5]of 0. 94 in predicting pass/fail at the FALANT [27]. A Nagel range of more than 10 has sensitivity of 0. 87 and specificity of 0. 57. Therefore, neither D15 nor Nagel Anomaloscope can predict the performance of an individual on the FALANT [27]. This shows that therefore one cannot conclude by a single clinical colour vision test if someone should be allowed to work in certain occupations.

Inconsistency between different standards can also mislead colour deficient individuals. Birch (2008) showed that the pass criteria used by the Civial Aviation Authority in UK and CIE lack internal consistency when applied to the H-W A [3]. It was proved that the colour deficient people who pass the first stage have only 50% chance to pass the second stage, and 25% to pass the third stage of the CAA examination [3]. The same follows for the CIE examination. A person who has passed the first stage has only 50% to pass the second stage. Therefore there is no evidence to suggest that successful colour-deficient applicants have significantly better hue discrimination ability than colour deficient people who fail. It was also proven that signal lights cannot be easily identified in dark as previously assumed [3].

Hovis (2008) decided to investigate the repeatability of H-W A test for several scoring criteria in 2 separate visits [18]. The results of the study showed that most colour vision defects fail the H-W A regardless of the scoring criteria and that the individuals who confused between red and green did not come close to passing the H-W A [18]. The repeatability for failing the H-W A on separate visits was over 90% regardless of scoring criteria because the colour vision defects failed the test with numerous errors. Agreement for passing at both visits was lower, ranging from 2. 5-8%. The finding supports the need to present at least 3 runs of the nine pairs and basing the pass/fail criteria on the total number of errors. The criterion that allows 2 errors on 3 runs is reasonably repeatable, minimizes the number of individuals who pass the lantern at first session and fail in the later, and passes all normal CV in the first visit.

Ishihara is used to select applicants for employment in occupations such as electronics and transport that require good colour vision and a circular diagram should be used as a pass criterion and a single transformation of adjacent hues in the arrangement is allowed to pass [28]. Including either one or two isochromatic red-green errors favour protans and that is contraindicated if Farnsworth D15 Panel is used for occupational screening purposes. For aviation purposes, according to JAR " Ishihara test (24 plate version) is to be considered pass if the first 15 plates are identified without error, without uncertainty or hesitation (less than 3s per plate)" [8].

Cole et al. (2008) simulated the precision approach path indicator (PAPI) signals used in aviation and required the colour vision normals and defects to name them in the dark [23]. Only 19% of colour vision defects passed the lantern test, and only 4% made no errors recognising the PAPI signals at high intensity. All 52 colour vision normals passed the lantern test, however out of that, only 50 were able to recognise the simulated PAPI signals without errors at high intensity [23]. This study shows that passing the lantern test does not ensure that a colour vision deficient per