Color Vision Testing by Farnsworth Lantern and Ability to Identify Approach-Path Signal Colors

Barry L. Cole and Jennifer D. Maddocks

Cole BL, Maddocks JD. *Color vision testing by Farnsworth lantern and ability to identify approach-path signal colors.* **Aviat Space Environ Med 2008; 79:585–90.**

Introduction: It is presumed that pilots with abnormal color vision who pass the Farnsworth lantern test can distinguish aviation signal lights including the red and white lights of the Precision Approach Path Indicator (PAPI). The investigation of the FedEx Flight 1478 crash at Tallahassee airport in 2002 raises doubts about this presumption. It found a contributory factor was that the pilot had difficulty distinguishing the PAPI signals because of his deficient color vision (DCV) even though he had passed the Farnsworth lantern. This paper reports on the ability of subjects with DCV who pass the Farnsworth lantern to distinguish PAPI signal colors. ***Methods:*** Under a good visibility and a marginal visibility condition, 52 DCV subjects and 52 with normal color vision (NCV) named the colors of simulated PAPI signal lights observed in the dark. Subjects were tested with the Farnsworth lantern and a comprehensive battery of other color vision tests. ***Results:*** The 10 DCV subjects who passed the Farnsworth lantern made significantly more errors naming PAPI signals than the NCV subjects and 80% made more errors than the worst performing NCV subject. Some confused the red and white signals on more than 10% of occasions. ***Conclusions:*** Passing the Farnsworth lantern test does not ensure that DCV pilots can distinguish PAPI signal colors. The criterion for passing the lantern test should be made more stringent. In addition the design of PAPI signals can be improved by a better choice of the white color and by providing a redundant non-color cue.

Keywords: abnormal color vision, aviation color vision standard, aviation signal lights, color vision tests, PAPI.

AN IMPORTANT AVIATION signal system is the Precision Approach Path Indicator (PAPI), which provides pilots with information as to whether their aircraft is above, below, or on the correct approach path for landing. It displays four signal lights that can be either red or white: if the aircraft is on the correct approach path, two of the four signal lights are red and two are white; if the aircraft is too low, three or four of the lights are red; and if the aircraft is too high, three or four are white. The signal system is entirely color dependent: the colors of the red and white signals have to be recognized for it to be of use.

Pilots are required to have normal color vision or, if they are among the 8% of men and 0.4% of women with defective color vision (DCV), they are required to show that they have the ability to recognize the colors used in air navigation (10). This is usually assessed using a lantern test, which simulates the task of recognizing colored signal lights used in maritime and air navigation. There are a number of different lantern tests: the Farnsworth lantern is used in the United States and Australia (1,6) while the Holmes Wright Type A, the Spectrolux, and the Beyne (Tritest L3) lantern tests are used in other countries (12).

The National Transportation Safety Board enquiry into the crash of Federal Express flight 1478 on July 26, 2002, found that the crash was due in part to the defective color vision of the pilot, which impeded his ability to interpret the red and white colors of the PAPI glidepath signals despite his having passed the Farnsworth lantern test (11). The enquiry recommended that the adequacy of the tests of color vision used in aviation be investigated to ensure they do identify pilots with abnormal color vision who have an impaired ability to perform color-related critical aviation tasks, including correct interpretation of glidepath information.

This question has been partially addressed by recent work. Cole, Lian, and Lakkis (2) showed that three-quarters of DCV subjects who pass the Farnsworth lantern test can recognize the colors of a 10-color surface color code without errors and that the remaining one-quarter make few errors, mostly confusing red, orange, and brown. Those who pass the Farnsworth lantern should be able to make use of surface color codes in aviation instruments, maps, and airport surface markings.

However, it has been recently shown that the Farnsworth lantern test passes some subjects who have a significantly impaired ability to recognize red, green, and white signals, including some who are likely to confuse the red and white colors of PAPI signals (3). This arises partly because the conventional protocol for giving the Farnsworth lantern test does not adequately sample the ability of the subject to recognize signal

From Clinical Vision Research Australia, Victorian College of Optometry, and the Department of Optometry and Vision Sciences, University of Melbourne, Victoria, Australia.

This manuscript was received for review in November 2007. It was accepted for publication in February 2008.

Address reprint requests to: Barry L. Cole, Department of Optometry and Vision Sciences, University of Melbourne, Victoria 3010, Australia; bcole@optometry.unimelb.edu.au.

DOI: 10.3357/ASEM.2245.2008

light colors. Some subjects will pass simply by chance because the number of observations made in the standard Farnsworth test is too small to give a reliable estimate of their true ability. Cole et al. (3) recommend that the protocol for administering the Farnsworth lantern be changed to increase sampling. They recommend 1) that the practice of passing applicants who make no errors on a single run of nine pairs of lights be abandoned; 2) giving all applicants with DCV at least two runs of the nine pairs of signal lights; and 3) that the criterion for passing be changed from no more than two errors to no more than one error. This would reduce the pass rate from 20% of those with abnormal color vision to 12% and reduce the risk of passing those likely to make errors recognizing aviation signal lights.

In a previous paper we reported an investigation of the ability of subjects with abnormal color vision to recognize the colors of PAPI signal lights and we reported errors for each class of abnormal color vision (4). **Table I** summarizes some of the key data from that paper. Subjects with normal color vision rarely make errors while two-thirds of those with abnormal color vision made more errors than the worst of the subjects with normal color vision and some made many errors. Protanomals and protanopes have a reduced sensitivity to red light and as a consequence may fail to see dim distant red signals. This previous paper did not report the performance of subjects who had passed or failed the Farnsworth lantern test, although the data had been obtained at the time. We have revisited the data of this earlier investigation to determine whether those who pass the Farnsworth lantern are able to recognize the colors of PAPI signal lights.

METHOD

A Farnsworth lantern was modified so that its signal lights simulated PAPI signals. The filters were changed so it presented seven red lights, seven white lights, and four blanks. The red and white colors were chosen taking into account the ICAO standard for the colors of aviation signal lights (9) and measurements of the colors of actual PAPI signals made by us and others. Full details of these measurements, and of other factors taken into account in deciding the colors to best represent the colors of PAPI signals, are given in our report to the Australian Civil Aviation Authority (5).

There were two whites. White 1 represented the color of a PAPI white signal viewed under good visibility conditions. Its chromaticity coordinates lie within the CIE class A domain of colors allowed for white signal lights (**Fig. 1**). White 2 represented the color of the white PAPI signal when dimmed or when attenuated by industrial haze over a distance of 0.5 km. Its chromaticity coordinates lie outside the yellow boundary of CIE Class B White, which is not uncommon for white signals when attenuated by the atmosphere. However, its chromaticity coordinates still lie within a color domain that was, prior to 2001, permitted for white maritime and aviation signals. The color of red signals is not affected by atmospheric scattering.

The spectral emissions of all lights were measured insitu using spectrophotometry by a photometric laboratory accredited by the National Association of Testing Authorities. Their CIE chromaticity coordinates were calculated from that data.

The blanks were included for two reasons. One was to reduce the effect of guessing: there would be a 50% chance of a correct answer if there were only two possible responses, red or white. The other reason was that protanope and protanomal subjects may not see the red lights because of their reduced sensitivity to red light. They might chose to identify lights they could not see as 'red' if red and white were the only two possible responses. The lights and the blanks were presented in vertically separated pairs, as is the case for the Farnsworth lantern test. The order of the colors and the blanks is shown in **Table II**.

The illuminances of the lights are set out in **Table III**. There are two sets of illuminances, one representing good visibility conditions and the other marginal visibility conditions. Our initial intention was to have one set of illuminances to simulate the brightness of PAPI signals when viewed at 1 nm when metrological visibility was 1.5 km. We measured the actual intensities of PAPI signals and took account of the published measurements of others to calculate by Allard's law the illuminances at a pilot's eyes generated by typical PAPI

TABLE I. ERRORS MADE BY SUBJECTS WITH NORMAL COLOR VISION AND THE VARIOUS CLASSES OF ABNORMAL COLOR VISION RECOGNIZING THE COLORS OF SIMULATED PAPI SIGNAL LIGHTS AT THE HIGH INTENSITY*.

	Number of Subjects	Percent Subjects Making: Zero Errors	Percent Subjects Making: More Errors Than Worst NCV	Error Rate (%): Red Named 'White' and Vice Versa: Mean	Error Rate (%): Red Named 'White' and Vice Versa: Worst Subject	Mean Occasions Red Signal Not Seen (%)
Normal color vision (NCV)	52	96		0.05	1.4	0
Protanomaly (PA)	13	23	38	2.4	5.7	4.0
Deuteranomaly (DA)	15	7	73	8.0	25.7	0.2
Protanopia (P)	12	25	58	2.4	20.0	2.9
Deuteranopia (D)[†]	12	0	92	11.8	32.9	0
All abnormal color vision	52	14	65	6.2		1.7

* From data of Cole and Maddocks (4). Data were collected at two intensity levels (see Table III). Only the results at the high level are summarized here. All subjects made more errors at the low intensity. PAPI = Precision Approach Path Indicator.
† One subject reported as a deuteranope in Cole and Maddocks (4) is now reclassified as deuteranomal.

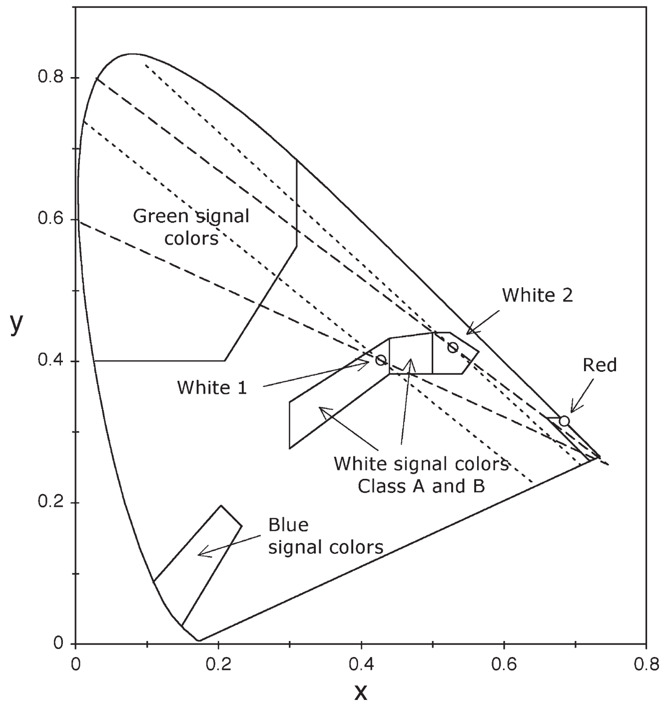

Fig. 1. CIE 1931 chromaticity diagram showing the x,y coordinates (white circles) of the red, White 1, and White 2 colors used in the simulation of PAPI signal lights. The boxes are the allowable domains of colors for red, white, green, and blue signal lights as defined by the CIE Standard S004/E-2001. The domain for white is divided into three areas. The two domains labeled Class A and B are recognized as suitable for white signals by CIE S004/E 2001. Prior to 2001 the third unlabeled area within which White 2 lies was allowed for signal systems that did not include yellow. However, whites which lie in Class B when viewed under poor atmospheric conditions become yellowish and shift into the unlabeled area of the white signal light domain The dashed lines show the colors that are confused with White 1 and 2 by protanopes (dashed lines) and by deuteranopes (dotted lines). These lines show that White 2 and red will look very much the same for both protanopes and deuteranopes and that White 1 and red will appear much the same for protanopes.

signals observed from 1 nm under meteorological visibility of 1.5 km. The calculated illuminances were of the order of 1 μlx for a red signal to 5.5 μlx for a white signal. Color vision normal subjects should be able to recognize the colors of signal lights having illuminances of this order since they are several times above chromatic threshold. However, a preliminary trial with color vision normal subjects showed that some made errors naming the colors at these illuminances and they were raised by a factor of three to ensure that all color vision normal subjects could recognize the colors with little chance of error. These illuminances were used to represent marginal visibility conditions and a second set of illuminances, double those of the marginal visibility illuminances, were used to represent good visibility conditions. Full details of the basis on which the intensity of the lights was determined are given in our Final Report to the Civil Aviation Authority (5).

The white signals were brighter than the red signals as occurs in practice since it is an ICAO requirement that the white PAPI signal have an intensity between 2 and 6.5 times that of the red signal (9). In theory this provides a brightness cue to differentiating the red and white colors. The observation distance was set at 3.8 m so the diameter of the lights subtended an angle of 1.8 min arc at the subject's eyes, replicating observation of a PAPI signal at 1 nm. The standard Farnsworth lantern test is given at an observation distance of 2.4 m, at which distance the lights subtend 2.9 min arc.

Subjects with DCV were recruited by letter from among patients who had previously attended the color vision clinic of the Victorian College of Optometry. An age-matched control group of subjects with normal color vision (NCV) was recruited from among staff and students. All subjects had a visual acuity of at least 6/7.5 in the better eye. The project was approved by the Joint Victorian College of Optometry and National Vision Research Institute Human Research Ethics Committee and subjects gave written informed consent to their participation in the study.

The color vision of all subjects was assessed using the Ishihara test for color blindness, which reliably differentiates normal from abnormal color vision; the Medmont C 100 test (Richmond Products, Albuquerque, NM), which differentiates protan and deutan color vision deficiency; the Farnsworth D15 test (Richmond Products), which tests severity of the deficiency; and the Nagel anomaloscope (Type 1 Schmidt and Haensch, Berlin, Germany), which classifies deficient color vision by type. These tests enabled a confident diagnosis of normal or abnormal color vision and the classification of color vision deficiency as protanomaly, deuteranomaly, protanopia, and deuteranopia. There were 52 NCV and 52 DCV subjects of whom 13 were protanomals, 15 deuteranomals, 12 protanopes, and 12 deuteranopes.

All subjects were tested with the standard Farnsworth lantern (MacBeth Corp, Newburgh, NY) in accordance with its usual protocols. It was given in a lit room at a test distance of 2.4 m. All subjects who made no errors on the first run of nine pairs were passed; those who made errors on the first run were given two further runs and those who made no more than two errors in those two runs were passed.

All subjects made observations with the Farnsworth lantern modified to simulate PAPI signals. The test was

TABLE II. COMBINATIONS OF PAIRS OF COLORS IN THE NINE POSITIONS OF THE MODIFIED FARNSWORTH LANTERN.

	1	2	3	4	5	6	7	8	9
Top	W1	R	R	Blank	W2	R	W1	Blank	W2
Bottom	Blank	R	W2	R	Blank	W1	R	W2	R

W = white, W1 is a CIE Class A white (bluish white), W2 is a yellowish-white representing a white seen through atmospheric haze. R = red. Blank is no signal.

TABLE III. ILLUMINANCES OF THE LIGHT STIMULI AT THE SUBJECTS' EYES (μLX).

Color	High Illuminance	Low Illuminance
White 1	35.3	17.6
White 2	17.6	8.8
Red	5.5	3.3

Illuminance is the amount of light per unit of area (m^2) in the plane of the subjects' eyes and depends on the intensity of the signal light, the distance from which it is observed, and the amount of light absorbed by the intervening atmosphere. Color signals can be recognized at night when illuminance is more than 1 μlx (7).

given in the dark after 6.5 min of dark adaptation. They were read standard instructions and the colors were demonstrated to them. The only answers permitted were 'white', 'red', or 'no light or blank'. Five runs of nine pairs were given at each of the two intensity levels, with each run starting at a predetermined random starting point. The order in which the high and low intensity levels were shown was alternated in successive subjects.

RESULTS

We have previously reported the results for the different classes of abnormal color vision (4) and these are summarized in part in Table I. In this paper we report the results in relation to passing or failing the standard Farnsworth lantern test. **Table IV** summarizes the results.

NCV Group

All the NCV subjects passed the Farnsworth lantern test without any error. Of the 52 NCV subjects, 50 made no errors recognizing the simulated PAPI signals at the high intensity. Two (3.8%) made one error each and in both cases the error was to name the White 2 as red. At the low intensity, seven NCV subjects (13%) made errors and the greatest number of errors was three. The most common error was to name the yellowish-white 2 as 'red', which was the error made by six NCV subjects on up to three occasions. Two subjects named red as 'white' at the low intensity, one on three occasions and once for the other subject.

Pass Farnsworth Lantern DCV Group

Of the 52 DCV subjects, 10 passed the Farnsworth lantern test. Three were protanomals and seven deuteranomals. They all had a 'mild' color vision deficiency in that they all passed the Farnsworth D15 test (< 2 diametrical crossings) and had a matching range at the anomaloscope of less than 28 units (Mean matching range = 13 units).

High intensity PAPI signals: Of the 10 Pass Farnsworth DCV group, 2 made no errors recognizing the PAPI signals at the high intensity. Another two made no more errors than the worst performing subject with normal color vision. However, average errors for the Pass Farnsworth group were significantly higher than that of the NCV group (t-test, $P = 0.006$) and 6 of the 10 performed less well than the worst performing NCV subject. One subject named red as white for 20% of the presentations of the red signal. This was the only kind of error made by this subject: he correctly named white and the blanks on all occasions. He is the 'worst subject' in Table IV for red/white errors among the Pass Farnsworth group. This subject was a very mild deuteranomal: he had a very narrow anomaloscope range of 3 units, passed the Farnsworth D15 test, and made no errors on the Farnsworth lantern.

Low intensity PAPI signals: The average number of errors of the Pass Farnsworth DCV group at the low intensity was significantly higher than that of the NCV group (t-test, $P = 0.001$) and one subject made 14%

TABLE IV. ERRORS MADE BY SUBJECTS WITH NORMAL AND ABNORMAL COLOR VISION RECOGNIZING THE COLORS OF SIMULATED PAPI SIGNAL LIGHTS.*

		Percent Subjects Making			Error Rate (%) Red Named 'White' and Vice Versa		
	Number of Subjects	Zero Errors	More Errors Than Worst NCV	Mean Error Rate (%): All Kinds of Error	Mean	Worst Subject	Mean Occasions Red Signal Not Seen (%)
Normal Color Vision	52						
High intensity signals		96		0.04	0.05	1.4	0
Low intensity signals		87		0.3	0.38	4.3	0
Both high and low		85		0.2	0.22	2.1	0
Abnormal Color Vision							
Pass Farnsworth Lantern	10						
High intensity signals		20	60	2.2	2.9	10.0	0
Low intensity signals		10	70	5.6	6.4	18.6	1.1
Both high and low		0	80	3.9	4.6	14.3	0.6
Fail Farnsworth Lantern	42						
High intensity signals		12	67	6.3	7.0	30.0	2.1
Low intensity signals		10	64	10.1	8.3	58.6	9.0
Both high and low		5	88	8.2	7.6	44.3	5.6

* Each subject was presented seven red, seven white, and four blanks in each run of nine pairs of signals and there were five runs for each visibility condition. Thus each subject responded to 35 red, 35 white, and 20 blanks for each visibility condition. PAPI = Precision Approach Path Indicator; NCV = normal color vision.

errors, mostly naming red as 'white'. Two of the three protanomals failed to see red signals at the low intensity; that is, they sometimes identified red signals as 'blanks'. They both did this for 5.7% of the red signals. Here it can be noted that there were few false positives; that is, blanks called 'red' or 'white'. This occurred only 7 times in the total of 2080 blanks presented to the 52 subjects with abnormal color vision in the high and low intensity conditions.

Fail Farnsworth Lantern DCV Group

The Fail Farnsworth lantern DCV group ($N = 42$) made significantly more errors than the Pass Farnsworth lantern group at both the high (t-test, $P < 0.001$) and low intensities (t-test, $P = 0.016$). Only 2 of the 42 subjects (5%) made 0 errors under both intensity conditions, but about 12% performed as well as the worst performing NCV subjects. On the other hand, one in five made more than 15% errors and some more than 30% errors.

The Fail Farnsworth lantern DCV group failed to see 2% of the high intensity red signals and 9% of the low intensity red signals. This error (calling the red signal 'blank') was almost exclusively made by the protanomals and protanopes whose color vision deficiency is always characterized by reduced sensitivity to red light. Only one deuteranomal and one deuteranope made this error.

DISCUSSION

Passing the Farnsworth lantern does not ensure that subjects with abnormal color vision will be able to recognize the colors of PAPI signals as well as subjects with normal color vision. DCV subjects who passed the Farnsworth lantern averaged 2% errors under the good visibility condition, which is significantly greater than the 0.04% error rate of the NCV subjects, and 60% of them made more errors than the worst NCV subject. One DCV subject who passed the Farnsworth lantern confused red and white on 10% of occasions. It is, therefore, not surprising that the pilot in FedEx flight 1478 crash, who had abnormal color vision but was reported to have passed the Farnsworth lantern test, had difficulty discerning the red and white colors of the PAPI glidepath signal system.

Consideration has to be given as to whether the higher chance of error with PAPI signals by pilots who have abnormal color vision but pass the Farnsworth lantern is an acceptable level of risk. Subjects with normal color vision will sometimes mistake the colors of distant or dim signal lights and in this investigation the group with normal color vision occasionally made errors, especially under the marginal visibility (low intensity) condition (Table IV). However, the subject with the worst error rate for the two visibility conditions combined made only 2.1% errors and his most common error by far was to name White 2 as 'red'. This is a 'safe' error since it instructs the pilot to increase altitude. Only on 3 occasions did the color vision normal subjects make the 'unsafe' error of naming red as 'white': 1 of the 52 normal color vision subjects made this error 3 times and 1 made it once, but did so only under the marginal visibility condition.

In contrast the Pass Farnsworth DCV group had a total error rate 20 times greater than the NCV group, and the worst performing subject misnamed red and white on 14% of occasions. On average the Pass Farnsworth group misnamed red and white on nearly 5% of occasions and some subjects sometimes did not see the red signal, although that occurred only under the marginal visibility condition (Table IV).

Although the DCV group who fail the Farnsworth lantern made significantly more errors than the pass group, some perform surprisingly well and made few errors with the simulated PAPI signals (Table IV): 10–12% made no errors in each of the two visibility conditions, and 5% made no errors in both visibility conditions combined. Even some of those with a very severe color vision deficiency made zero errors. However, it should not be inferred from this that these subjects have an ability to reliably distinguish red and white PAPI signal lights in practice. Their good performance can be attributed to two factors: one is the chance of guessing correctly since there were only three options, red, white, and blank. The other is the use of the brightness difference because the white signal is brighter than the red. This brightness difference is exaggerated for the protan subjects because they either have an anomalous red sensitive cone receptor pigment, or lack it altogether. In support of this explanation it can be noted that all but one of the 14 Fail DCV Farnsworth subjects who made very few errors in the good visibility condition were protans: they were able to correctly name the bright signal as 'white' and the dim signal as 'red'.

It does not follow that the Fail Farnsworth DCV subjects could make use of this brightness cue when using PAPI during an approach. In this experiment, the intensities of the signals were constant: in the real world effective intensity will vary due to dimming and variations in atmospheric visibility. The brightness difference cue might be useful when there is a mix of white and red in the PAPI display, but not when the display is all red or all white. While protan subjects may sometimes be helped by the brightness difference between red and white signals, they may sometimes fail to see the red signal because of their reduced sensitivity to red light. Table I shows that protan subjects fail to see the red signal on 3 to 4% of occasions under the good visibility condition, and even higher under the marginal visibility condition (4), an error not made by the NCV subjects.

There are two options if these higher risks of error by the Pass Farnsworth DCV group are considered to be unacceptable. One is to make the aviation color vision requirement more stringent and the other is to improve the design of PAPI signals. The Commission Internationale de L'Éclairage (8) recommends that normal color vision should be required for pilots of scheduled passenger aircraft, especially large aircraft, and that other commercial pilots be required to pass a lantern test and not have a protan (red-deficient) color vision deficiency. Cole, Lian, and Lakkis (3) show that the current procedure for administering the Farnsworth lantern provides insufficient sampling and passes some applicants for a pilot's license who are likely to make errors with color codes. They recommend that the criterion for passing the Farnsworth lantern should be no more than one error in two runs of the test, which would reduce the pass rate from 20 to 12%.

The latter option simply reduces risk by passing a smaller number of persons with DCV. It does not ensure that those who pass will make no errors with PAPI signal lights. In this study, 6 of the 10 subjects who passed the Farnsworth lantern would still pass if the pass criterion was no more than 1 error. All but one of the six made more errors with the simulated PAPI signals than the worst NCV subject, and two made a considerable number of errors.

The design of the PAPI signal system could be improved in two ways: one is to specify that the white signal be a bluish-white with a chromaticity in the left hand part of the CIE White Class A signal color domain (Fig. 1). This would be a more recognizable white under good visibility conditions (7) and when its color is shifted toward yellow by dimming or atmospheric haze, its chromaticity would still lie in the Class A domain for white signals or at worst in the Class B domain. The other is to provide a non-color redundant cue such as making the red lights flash or having double red lights.

REFERENCES

1. Birch J, Dain SJ. Performance of red-green color vision deficient subjects on the Farnsworth lantern (FALANT). Aviat Space Environ Med 1999; 70:62–7.
2. Cole BL, Lian KY, Lakkis C. Color vision assessment: can pilots who pass the Farnsworth lantern test recognize surface color-codes? Aviat Space Environ Med 2007; 78:21–5.
3. Cole BL, Lian KY, Lakkis C. Color vision assessment by Farnsworth lantern: results using alternative pass-fail criteria. Aviat Space Environ Med 2008; 79:509–13.
4. Cole BL, Maddocks JD. Protans and PAPI: recognition of a two colour code by persons with defective colour vision. In: Drum B, ed. Colour vision deficiencies XII. Dordrecht, Netherlands: Kluwer; 1995:495–500.
5. Cole BL, Maddocks JD. A simulation of PAPI signals for testing the colour vision of applicants for a pilot's licence. Final report to the Australian Civil Aviation Authority. Melbourne, Australia: Victorian College of Optometry, University of Melbourne; 1993.
6. Cole BL, Vingrys AJ. A survey and evaluation of lantern tests of color vision. Am J Optom Physiol Opt 1982; 59:346–74.
7. Commission Internationale de L'Éclairage. Review of the official recommendations of the CIE for the colours of signal lights. Technical Report No 107. Vienna: CIE; 1994.
8. Commission Internationale de L'Éclairage. Recommendations for colour vision requirements for transport. Technical Report No 143. Vienna: CIE; 2001.
9. International Civil Aviation Organization. International standards and recommended practices, aerodromes. Annex 14, 109. Montreal, Canada: ICAO; 1990.
10. International Civil Aviation Organization. International standards and practices. Annex 1 to the convention on international civil aviation. Personnel licensing. Chapter 6. Montreal, Canada: ICAO; 2001.
11. National Transportation Safety Board. Collision with trees on final approach: Federal Express flight 1478, Boeing 727-232, N497FE, Tallahassee, Florida, July 26, 2002. Aircraft accident report NTSB/AAR-04/02. Washington, DC: NTSB; 2004.
12. Squire TJ, Rodriguez-Carmona M, Evans AD, Barbur JL. Color vision tests for aviation: comparison of the anomaloscope and three lantern types. Aviat Space Environ Med 2005; 76:421–9.