A Performance Comparison of Color Vision Tests for Military Screening

David V. Walsh; James Robinson; Gina M. Jurek; José E. Capó-Aponte; Daniel W. Riggs; Leonard A. Temme

BACKGROUND: Current color vision (CV) tests used for aviation screening in the U.S. Army only provide pass-fail results, and previous studies have shown variable sensitivity and specificity. The purpose of this study was to evaluate seven CV tests to determine an optimal CV test screener that potentially could be implemented by the U.S. Army.

METHODS: There were 133 subjects [65 Color Vision Deficits (CVD), 68 Color Vision Normal (CVN)] who performed all of the tests in one setting. CVD and CVN determination was initially assessed with the Oculus anomaloscope. Each test was administered monocularly and according to the test protocol. The main outcome measures were test sensitivity, specificity, and administration time (automated tests).

RESULTS: Three of the four Pseudoisochromatic Plate (PIP) tests had a sensitivity/specificity > 0.90 OD/OS, whereas the FALANT tests had a sensitivity/specificity > 0.80 OD/OS. The Cone Contrast Test (CCT) demonstrated sensitivity/specificity > 0.90 OD/OS, whereas the Color Assessment and Diagnosis (CAD) test demonstrated sensitivity/specificity > 0.85 OD/OS. Comparison with the anomaloscope ("gold standard") revealed no significant difference of sensitivity and specificity OD/OS with the CCT, Dvorine PIP, and PIPC tests. Finally, the CCT administration time was significantly faster than the CAD test.

DISCUSSION: The current U.S. Army CV screening tests demonstrated good sensitivity and specificity, as did the automated tests. In addition, some current PIP tests (Dvorine, PIPC), and the CCT performed no worse statistically than the anomaloscope with regard to sensitivity/specificity. The CCT letter presentation is randomized and results would not be confounded by potential memorization, or fading, of book plates.

KEYWORDS: military, aviation.

Walsh DV, Robinson J, Jurek GM, Capó-Aponte JE, Riggs DW, Temme LA. *A performance comparison of color vision tests for military screening.* Aerosp Med Hum Perform. 2016; 87(4):382–387.

Optimal color vision in the current complex color-coded operational environment is vitally important to today's U.S. Army Service Members and other military members. An individual's ability to see colors depends on intricate retinal mechanisms that involve two types of light sensitive cells: rods and cones. Both of these cells convert light energy of different wavelengths (λ) into signals that carries information via the optic nerve back to the brain. Of the two light sensitive cells, only cones are sensitive to color with the three primary cone types being red (long spectral λ: 620–750 nm), green (middle spectral λ: 495–570 nm), and blue (short spectral λ: 450–495 nm). The most common deficit in color vision is congenital, showing the X-linked recessive pattern (Red-Green [R-G]), and therefore seen most frequently in the male population (8% vs. 0.4% female). R-G deficiencies are disqualifying for many military specialties, including aviation, public affairs, bridge crewmember, and ordnance, to name a few.

Color vision tests can be categorized into four subtypes: pseudoisochromatic plate (PIP), arrangement (e.g., Farnsworth D-15 [D15]), matching (e.g., anomaloscope), and naming tests (e.g., Farnsworth Lantern [FALANT]).[7] The anomaloscope is considered the "gold standard" test for diagnosing acquired and congenital color vision deficiencies,[1,11,17] which requires the viewer to adjust two colors until the colors match. However,

From the Vision Protection and Performance Division, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL; Optometry Clinic, Carl R. Darnall Army Medical Center, Fort Hood, TX; and Department of Optometry, Womack Army Medical Center, Fort Bragg, NC.

This manuscript was received for review in June 2015. It was accepted for publication in December 2015.

Address correspondence to: LTC David V. Walsh, Vision Protection and Performance Division, U.S. Army Aeromedical Research Laboratory, 6901 Farrel Rd, Fort Rucker, AL 36362; david.v.walsh.mil@mail.mil.

DOI: 10.3357/AMHP.4391.2016

the anomaloscope is a time-consuming, expensive device, and the results can be hard to interpret. Therefore, anomaloscopes are most often found in research settings. A PIP test involves the observers identifying a colored number (most often), or tracing a figure, embedded in a homogeneous background that differs only in color.[7] The Dvorine PIP test has provided the initial level screening for color vision in the U.S. Army for over five decades. However, use of the Dvorine PIP test has been problematic, particularly for Army aviation where color vision plays an important role in ensuring safe flight performance. Aircrew candidates are incorrectly classified by the Dvorine PIP test as color vision normal (CVN) due to improper test administration such as incorrect lighting and the use of worn out PIP plates with fainted color pigments. In addition, memorization of the PIP plates by highly motivated candidates has been problematic, forcing the services to seek stimulus randomized automated tests to overcome this shortfall. A study conducted by the U.S. Air Force (USAF) determined the sensitivity of the Dvorine PIP test, using 10 of 14 correct responses as the passing criterion, for trained and pilot applicants was only 78% and 50%, respectively. In the same study, the sensitivity of this test increased to 96% and 86%, respectively, when using a stricter 12 of 14 correct as the passing criterion.[15] Based on this study, in 2007 the U.S. Army changed its aeromedical standards for color vision testing to adopt the 12 of 14 correct as the color vision-passing criterion. Although this change in score standard increased the sensitivity of the test, it decreased the test specificity, therefore identifying a large number of false positives [i.e., CVN identified as color vision deficient(CVD)], which in turn increases the number of subjects that require the second level of color vision assessment using the FALANT test.[3,8] The FALANT is a naming test that requires the observer to name two lights displayed vertically when given three choices: red, green, or white. The test is designed to identify individuals with significant R-G CVD, but does not determine the type or the severity of CVD.[2,4,10] Current U.S. Army aeromedical standards for the FALANT allow for no errors in identifying the R-G or white (nine pairs of light combination) in only one run, despite a published study recommending a practice run and two test runs.[3] Those individuals failing the FALANT are considered disqualified for aviation duty. However, multiple studies have shown the FALANT also allows many moderate and severe color defective individuals to pass, leading the USAF to discontinue this test.[5,6,9]

Furthermore, the first (Dvorine) and second (FALANT) level tests used by the U.S. Army are problematic for three other reasons. First, the tests provide only a 'pass-fail' determination without quantifying the severity of the CVD and often times incorrectly identify the candidate as having normal color vision when they are in fact color deficient. Second, the Dvorine PIP test, which is the primary method of color vision screening in the U.S. Army, is no longer commercially available, therefore a replacement test is required to assess color vision. Finally, neither test screens for tritan CVD, usually associated with acquired ophthalmic conditions. Another PIP-type test, the PIP Ishihara Compatible (PIPIC), was developed to quickly screen for normal color vision as well as congenital and acquired color vision defects and can classify the type of defect (i.e., protan, deutan, and tritan). However, the PIPIC has not been evaluated for military use. An automated color vision test, the Cone Contrast Test (CCT), has been recently utilized by the USAF School of Aerospace Medicine (USAFSAM) and is now commercially available. The CCT is a computer software-generated clinical color vision test that indicates type (red, green, or blue) and severity (mild to severe) of CVD and quantifies color vision performance.[13,14] The CCT is designed to detect hereditary color vision loss and also reveals acquired color vision loss. Another automated color vision tester, the Color Assessment and Diagnosis (CAD) test, reportedly provides an accurate assessment of color vision with similar reliability and validity as the anomaloscope, but it is easier to administer.[16]

The purpose of the present study was to determine the optimal, commercially available, color vision test based on sensitivity and specificity against the accepted "gold standard" color vision test (anomaloscope), as well as time to administer. This study will help refine color vision testing protocols and standards for air and ground warfighters in the U.S. Army and other military members.

METHODS

Subjects

There were 133 U.S. military personnel (active duty, national guardsmen, reservists or retired) who participated in the study. For inclusion into the study, subjects had either known color vision problems (congenital or acquired) or normal color vision, and were over 18 yr of age. All subjects recruited were seen by an eye doctor at the optometry clinic for a comprehensive eye exam prior to volunteering for the study. The subjects were divided between two groups, CVD ($N = 65$) and CVN ($N = 68$), based off failure or success of the Oculus anomaloscope. Demographic information on the subjects is presented in **Table I.** The study was approved by the Brooke Army Medical Center (BAMC) Institutional Review Board and U.S. Army Medical Research and Materiel Command (USAMRMC) Office of Research Protection. Informed consent was obtained from all volunteers before participating in the study.

Equipment

The seven color vison tests performed are shown in **Fig. 1**. All PIP test books were newly purchased and a daylight HRR illuminator (Richmond Products, Albuquerque, NM) was used with a "daylight" fluorescent bulb with the PIP books on a stand so the subject's line of sight was at right angles to the plates. A monitor alignment tool was used for the CCT to ensure subjects were at a correct angle for testing. High and low contrast acuity measurements were taken with the Rabin Super Vision Test (Precision Vision Inc., La Salle, IL).

Procedures

After classifying subjects as CVD or CVN with the anomaloscope, seven color vision tests were performed monocularly according to the manufacturer's instructions included with

Table I. Demographics.

	CVD $\bar{x} \pm$ SD	CVN $\bar{x} \pm$ SD
Age (yr)	33.17 ± 10.54	34.52 ± 11.70
Gender		
Male	65 (100%)	51 (75%)
Female	–	17 (25%)
Visual Acuity		
HCVA (20/)		
OD	20.15 ± 0.88	19.01 ± 2.89
OS	20.08 ± 0.62	18.99 ± 2.71
LCVA (20/)		
OD	34.23 ± 10.20	33.12 ± 9.89
OS	33.08 ± 8.12	33.00 ± 10.38

CVD = Color Vision Deficient; CVN = Color Vision Normal; HCVA = High Contrast Visual Acuity; LCVA = Low Contrast Visual Acuity; OD = Right eye; OS = Left eye.

each test. All tests were performed with subjects best visual acuity correction, if required (no tinted contacts or tinted glasses allowed), under normal room lighting. Test order was randomized to reduce the order effect and pass/fail criteria for each test is listed in **Table II**. All PIP tests were performed between 20-30 inches, and subjects were given up to, but no more than 5 s per plate for a response. The FALANT test was performed at an 8-ft (2.44 m) distance, and a trial run was performed prior to data collection for subject understanding of the test procedure. A calibration was performed on the CCT once a month. Test distance for the CCT was 3 ft (0.91 m), and CAD between 51–59 in (1.3–1.5 m). High and low contrast acuity measurements were taken monocularly at 4 m and the total time to complete testing was approximately 75 min per subject. During testing, subjects were instructed to inform the examiner if they were getting tired or uncomfortable, and breaks were encouraged.

Statistical Analysis

Monocular sensitivity and specificity were calculated for each test. McNemar's test was performed on each color vision test to answer two questions: 1) are test results equal in both eyes; and

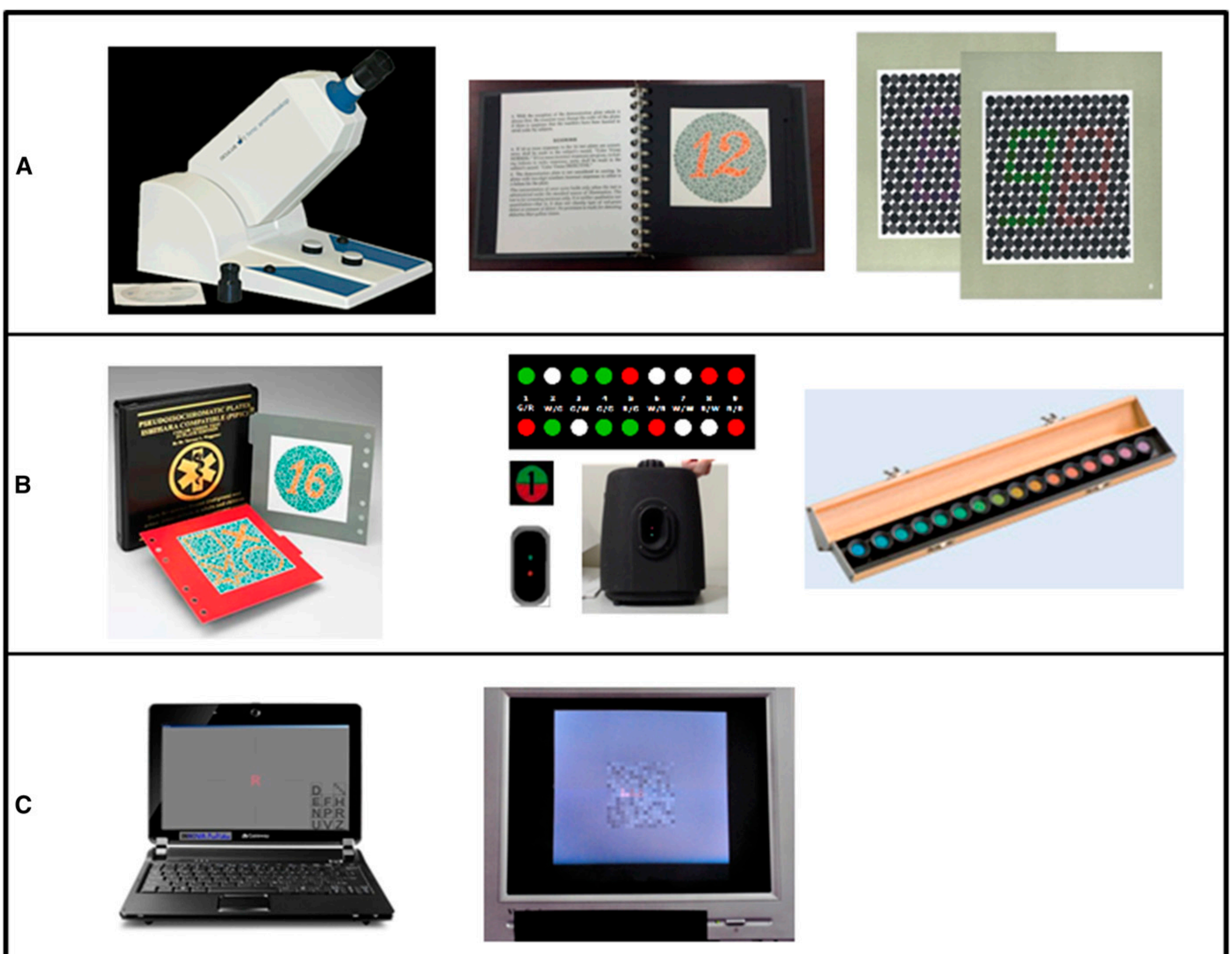

Fig. 1. Color vision test battery, from left to right in each row: A) Oculus Anomaloscope, Dvorine PIP, and SPP2; B) PIPIC, FALANT, and D15; C) CCT and CAD test.

Table II. Pass/Fail Criteria for Color Vision Tests.

TEST	PASSING SCORE	CVD CLASSIFICATION
PIP Dvorine	miss 2 or less plates of 14 plates	Fail if miss 3 or more plates
PIP2 (SPP2)	miss 1 or less plate of 10 plates	Fail if miss 2 or more plates
PIPIC (first 14 plates)	miss 2 or less plates	
PIPIC (plate #15)		Strong Protan = sees 5
		Strong Deutan = sees 3
		Mild Protan = sees 3 & 5, but 5 easier
		Mild Deutan = sees 3 & 5, but 3 easier
PIPIC (last 2 plates)	all plates correct	
FALANT	no errors on any run	
Farnsworth D-15	no major errors deviating	Crossing line along protan, deutan or tritan reference line
Anomaloscope (R/G)†	34-46 / 15 (expected 40/15)	Match within protan or deutan areas
Anomaloscope (B/G)†	42-58 / 50 (expected 50/50)	Tritan if outside normal area
CCT	score ≥ 75 on each color	Protan, deutan or tritan based on the affected color (< 75)
CAD		Normal or type of deficiency

† Oculus Anomaloscope.

2) are test results significantly different from the anomaloscope. Finally, a Wilcoxon signed-rank test was used to analyze the total times to administer the automated tests. All significance levels were $P < 0.05$. Statistical analyses were performed with the Statistical Package for Social Sciences (SPSS) version 20.0 (SPSS Inc., Chicago, IL) and GraphPad Prism 6 (GraphPad Software Inc., San Diego, CA) software.

RESULTS

Sensitivity, specificity, and between-eye comparisons of each test are presented in **Table III.** There were no significant differences between the eyes on any color vision test in terms of sensitivity and specificity. The most sensitive test (compared to the anomaloscope) was the Dvorine PIP (OD: 1.0; OS: 0.98), whereas the tests with the highest specificity (OD/OS: 1.0) were the Farnsworth D-15 and SPP2. The Dvorine PIP and PIPIC tests had a sensitivity and specificity (if applicable) at or above 0.94 in each eye, whereas the SPP2 had ~10% lower sensitivity than the Dvorine and PIPIC tests. The FALANT had greater than 0.80 sensitivity and specificity in both one- and three-test administration. The CCT demonstrated high sensitivity (OD/OS: 0.97) and specificity (OD: 0.97; OS: 0.96), whereas the CAD showed lower sensitivity (OD/OS: 0.86) and specificity (OD: 0.85; OS: 0.90). Finally, the D-15 demonstrated low sensitivity (OD: 0.32; OS: 0.35), but optimal specificity (OD/OS: 1.0)

Statistical comparison between the anomaloscope ("gold standard") and the remaining color vision tests were performed on each eye separately (**Table IV**). In CVD subjects, significant differences were seen with the SPP2 (OD: χ^2=6.13, $P = 0.008$; OS: χ^2=7.11, $P = 0.004$), FALANT in both the first (OS: χ^2=6.13, $P = 0.008$) and three-test administration (OD: χ^2=8.10, $P = 0.002$; OS: χ^2=9.09, $P = 0.001$), D-15 (OD: χ^2=42.02, $P < 0.001$; OS: χ^2=40.02, $P < 0.001$), and CAD (OD/OS: χ^2=7.11, $P = 0.004$). With CVN subjects, significant differences were only shown with the CAD (OD: χ^2=8.10, $P = 0.002$; OS: χ^2=5.14, $P = 0.02$) test. Finally, times to administer the color vision tests were measured for the automated tests. On average, the administration time for the CCT and CAD tests were 6 and 12 min, respectively, which was significant ($P < 0.001$).

DISCUSSION

The primary aim of this study was to determine an optimal color vision test that can both accurately classify and quantify color vision defects in U.S. Army soldiers while being administered in a reasonable time-frame. All the PIP color vision tests demonstrated a mean sensitivity and specificity of greater than

Table III. Color Vision Tests' Sensitivity, Specificity, and Between-Eye Comparisons.

	SENSITIVITY			SPECIFICITY		
TEST	OD	OS	*P*-VALUE	OD	OS	*P*-VALUE
Cone Contrast Test (CCT)	0.97	0.97	1.0	0.97	0.96	1.0
Color Assessment and Diagnosis (CAD)	0.86	0.86	1.0	0.85	0.90	0.25
Farnsworth D-15 (D15)	0.32	0.35	0.50	1.0	1.0	1.0
Farnsworth Lantern (FALANT) – One run	0.92	0.86	0.22	0.96	0.96	1.0
FALANT – Three runs	0.85	0.83	1.0	0.97	0.99	1.0
Dvorine Pseudoisochromatic Plates (PIP)	1.0	0.98	1.0	0.96	0.96	1.0
Standard Pseudoisochromatic Plates 2 (SPP2)	0.88	0.86	1.0	1.0	1.0	1.0
Pseudoisochromatic Plate Ishihara Compatible (PIPIC)	0.98	0.98	1.0	0.96	1.0	0.25
PIPIC, Plates 15,16,17† (CVD only)	0.94	0.95	1.0	–	–	–

† Plate 15 is used to classify type of R-G color vision deficiency and plates 16,17 are used to identify B-Y color vision deficiency.

Table IV. Statistical Comparisons Between Color Vision Tests and Anomaloscope.

TEST	CVD (SENSITIVITY)		CVN (SPECIFICITY)	
	OD (*P*-VALUE)	OS (*P*-VALUE)	OD (*P*-VALUE)	OS (*P*-VALUE)
Cone Contrast Test (CCT)	0.50	0.50	0.50	0.25
CAD	0.004*	0.004*	0.002*	0.02*
Farnsworth D-15 (D15)	< 0.001*	< 0.001*	1.0	1.0
Farnsworth Lantern test (FALANT) – One run	0.06	0.008*	0.25	0.25
FALANT – Three runs	0.002*	0.001*	0.50	1.0
Dvorine Pseudoisochromatic Plates (PIP)	1.0	1.0	0.25	0.25
Standard PIP 2 (SPP2)	0.008*	0.004*	1.0	1.0
PIP Ishihara Compatible (PIPIC)	1.0	1.0	0.25	1.0
PIPIC Plates 15,16,17 (CVD only)	0.13	0.25	–	–

* $P < 0.05$.

0.80 with the PIPIC test demonstrating the overall highest sensitivity (0.98) and specificity (0.98). In comparing the automated CCT and CAD tests, the CCT demonstrated ~10% mean increase in identifying those with CVD (0.97 vs. 0.86) and passing CVNs (0.97 vs. 0.88). Seshadri et al. found sensitivities and specificities greater than 0.90 with the CAD test; however, their screening test duration was 90 s vs. the present study's 12 min for the full test.[16] Some subjects in the present study did complain of the long test duration, and shorter screening test time options that are available with the CAD test (e.g., aviation test) could produce a higher sensitivity and specificity for performance. The FALANT exhibited adequate mean sensitivity and specificity when performed once (0.89 sensitivity; 0.96 specificity) or three times (0.84 sensitivity; 0.97 specificity), which agrees with similar findings from Cole and Maddock's study (0.81 sensitivity; 1.0 specificity).[5] However, the present study did demonstrate ~5% increase in pass rate by the third test in those with color vision deficits, which may indicate a practice effect. This increase in pass rate with multiple testing contradicts findings seen by Cole et al.[3] that found "10% of those who pass" on the first run will make "many errors" when additional runs are administered. One explanation for the differences in the studies could be the Cole et al. study had a ~50% higher sample size (100 vs. 65), and the increase in pass rate seen in the present study was not statistically significant ($P = 0.25$). Finally, the D-15 test demonstrated poor mean sensitivity (0.33), but a high specificity (1.0), which has been reported in prior studies.[12,18] However, the D-15 test is a dichotomous test that differentiates between mild and moderate/severe forms of color vision defects. Hence, the D-15 test intentionally passes individuals with mild color deficiency, individuals the other tests identify, which in turn would lead to the D-15 having a low sensitivity in those with CVD.

In comparison to the anomaloscope, the automated CCT and two PIP tests (PIPIC and Dvorine) performed no statistically worse vs. the "gold standard" in both sensitivity and specificity. We believe this is the first study to validate the PIPIC high performance ability in terms of both sensitivity and specificity. An advantage of the PIPIC and CCT is they both provide a pass/fail determination and the type and level of the color vision defect, if present. In addition, both screen for B-Y defects that are most commonly seen in retinal pathology. On the other hand, the Dvorine PIP is best at detecting R-G defects.[18] The high sensitivity of the Dvorine PIP seen in the present study was not observed by Rabin et al.; however they did find the CCT had high comparability to the anomaloscope.[14] The differences in sensitivity performance with the Dvorine PIP test between the two studies may highlight some of the potential issues with PIP-type color vision tests. It is worth noting that the research assistants who collected data in the present study believed the PIP tests had too many variables for optimal testing performance (e.g., test lighting, condition of the book).

A limitation to all color vision screening tests is they only determine color vision function, not functional color vision. Color vision function and functional color vision can be looked at as separate entities. For example, an individual may fail a color vision function test (e.g., Dvorine PIP), but can functionally perform their job specialty. Future research studies can explore the viability of testing functional color vision (e.g., recognizing PAPI lights) when a service member fails a standard color vision function test. Correlating both optimal color vision function and functional color vision tests can provide optimal color standards in both screening for defects and requirements for individual job specialties.

CONCLUSION

In recent years, automated color vision tests have been a step forward from the traditional PIP, arrangement, and naming tests. Results from the present study indicated the automated CCT and CAD tests are both effective, stand-alone color vision tests. However, the CCT demonstrated higher sensitivity and specificity and showed no significant differences in performance compared to the anomaloscope. Two PIP-type tests, Dvorine and PIPIC, also demonstrated no significant difference in performance compared to the anomaloscope. This suggests that if certain PIP color vision tests are performed using the correct testing protocol (e.g., correct lighting, distance, plate conditions), these can be reliable color vision screening tests. However, PIP tests may have too many instruction variables for optimal testing performance in a military environment with high technician turnover. In addition, PIP answers can be searched online and highly motivated individuals (common in the military) may falsely pass the test. Technicians can randomize PIP presentations; however this increases the mental workload on the technician when answers to the PIP test results are listed on printed score sheets in sequential order. Both automated tests in our study present randomized letters (CCT) or patterns (CAD). The CCT has preprinted score sheets that have the randomized letter sequence in order, so no additional mental workload is required for the technician. For the CAD test, the results are automatically stored in the computer. With increasing automation and computerized color vision tests demonstrating high performance in the present study, it is recommended the U.S. Army implement automated color vision testing, such as the CCT, that is currently being utilized by other U.S. military services. Automated testing may overcome current pitfalls associated with memorization of the plates and incorrect administration of PIP-type tests.

ACKNOWLEDGMENTS

This research was sponsored in part by the Postgraduate Research Participation Program at the U. S. Army Aeromedical Research Laboratory administered by the Oak Ridge Institute of Science and Education through an interagency agreement with the U.S. Department of Energy and USAMRMC.

The views, opinions, and/or findings contained in this paper are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless designated by other official documentation. None of the authors has financial or other interest in the color vision tests.

Authors and affiliations: David V. Walsh, O.D. , Gina M. Jurek, C.O.T., Daniel W. Riggs, M.S., and Leonard A. Temme, Vision Protection and Performance Division, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL; James Robinson, O.D., FAAO, Optometry Clinic, Carl R. Darnall Army Medical Center, Fort Hood, TX; and José E. Capó-Aponte, O.D., Department of Optometry, Womack Army Medical Center, Fort Bragg, NC.

REFERENCES

1. Barbur JL, Rodriguez-Carmona M, Harlow JA, Mancuso K, Neitz J, Neitz M. A study of unusual Rayleigh matches in deutan deficiency. Vis Neurosci. 2008; 25(3):507–516.
2. Birch J, Dain SJ. Performance of red-green color deficient subjects on the Farnsworth Lantern (FALANT). Aviat Space Environ Med. 1999; 70(1):62–67.
3. Cole BL, Lian KY, Lakkis C. Color vision assessment: fail rates of two versions of the Farnsworth lantern test. Aviat Space Environ Med. 2006; 77(6):624–630.
4. Cole BL, Lian KY, Lakkis C. Can color vision defective subjects who pass the Farnsworth lantern test recognize surface color codes? Aviat Space Environ Med. 2007; 78(1):21–25.
5. Cole BL, Maddocks JD. Color vision testing by Farnsworth lantern and ability to identify approach-path signal colors. Aviat Space Environ Med. 2008; 79(6):585–590.
6. Cole BL, Vingrys AJ. Who fails lantern tests? Doc Ophthalmol. 1983; 55(3):157–175.
7. Dain SJ. Clinical colour vision tests. Clin Exp Optom. 2004; 87(4-5): 276–293.
8. Hackman RJ. Predicting Farnsworth Lantern success with a six-plate series of the Ishihara pseudoisochromatic plates. Mil Med. 2001; 166(12): 1046–1048.
9. Hackman RJ, Holtzman GL, Walter PE. Color vision testing for the U.S. Naval Academy. Mil Med. 1992; 157(12):651–657.
10. Hovis JK. Repeatability of the Holmes-Wright type A lantern color vision test. Aviat Space Environ Med. 2008; 79(11):1028–1033.
11. Moreland JD, Kerr J. Optimization of stimuli for trit-anomaloscopy. Mod Probl Ophthalmol. 1978; 19:162–166.
12. Pease PL, Allen J. A new test for screening color vision: concurrent validity and utility. Am J Optom Physiol Opt. 1988; 65(9):729–738.
13. Rabin J. Quantification of color vision with cone contrast sensitivity. Vis Neurosci. 2004; 21(3):483–485.
14. Rabin J, Gooch J, Ivan D. Rapid quantification of color vision: the cone contrast test. Invest Ophthalmol Vis Sci. 2011; 52(2):816–820.
15. Rabin RC, Gooch JM, Ivan DJ, Linnemeyer S, Foxworth M. Sensitivity of color vision screening: alternatives for the future. [Abstract] Aviat Space Environ Med. 2007; 78(3):285.
16. Seshadri J, Christensen J, Lakshminarayanan V, Bassi CJ. Evaluation of the new web-based "Colour Assessment and Diagnosis" test. Optom Vis Sci. 2005; 82(10):882–885.
17. 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(5):421–429.
18. Vu BL, Easterbrook M, Hovis JK. Detection of color vision defects in chloroquine retinopathy. Ophthalmology. 1999; 106(9):1799–1803; discussion, 1804. doi: 10.1016/S0161-6420(99)90338-X