Colour Vision Testing for Selection of Civil and Military Pilots in India: A Comparative Study of Four Different Testing Methods

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Abstract

The Ishihara and the Martin Lantern Test (MLT) are the currently recommended tests for aviation colour vision testing in India. There are many anecdotal reports of conflicting results for these tests from different centres. This study was therefore conducted to compare these two tests and two other standard tests, the Farnsworth D15 and Heidelberg Multi-Colour anomaloscope(HMC) in assessing colour vision among 225 aspiring aviators for military flying and civil aviation prospectively over 20 months. Experienced colour normal pilots also tested as controls. All the four tests showed variable results in passing/failing same individuals with maximum variance attributable to the MLT and better correlation obtained on eliminating MLT. Comparing each test with HMC taken as gold standard, the best correlation was seen with the Ishihara and least with MLT. The D15 passed those with milder defects, failed those with severe anomaly and correlated well with Ishihara. The anomaly quotient of the anomalous was significantly different from colour normal controls. The study indicates that functional tests such as the MLT may not be reliable in assessing colour vision deficiency accurately and hence there is a need to include diagnostic tests such as the anomaloscope and the D15 in the testing protocol.

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Key words: colour vision, aviation, Ishihara, Martin Lantern test, Farnsworth D15, Heidelberg anomaloscope.

Introduction

Colour coding is often used in aviation to make visual information more conspicuous. These include colour visual display in the cockpit, external visual cues such as airfield lighting, aircraft formation lights, coloured smoke or light signals used in military and colour coding for segmentation and grouping operation. It is estimated that approximately 4% of the human population (8-10 % males and 0.4% females) are congenitally colour deficient [1, 2].These individuals, who have no other visual deficit, may pass undetected unless tested for their colour perception. Though many tests for colour vision are available, there is no consensus on the ideal method, with different countries using different tests [3, 4].Studies comparing these tests have shown variable results for different tests [5, 6].Testing with a comprehensive battery of colour vision tests as is used in clinical settings [7, 8] cannot be done for occupational screening where we need simple, quick, and reliable tests. In India, the pseudoisochromatic plates (Ishihara and Tokyo Medical College) and the Martin Lantern test (MLT) are the colour vision tests [9], currently recommended for both military and civil aviation aspirants who are evaluated at medical centres of the Indian Air Force (IAF). There are manyanecdotal reports of conflicting results for these tests from different centres. This prospective study was therefore conducted to evaluate colour perception among applicants for military and civil aviation using these two tests and two other standard tests, namely the Heidelberg Multicolour Anomaloscope(HMC) and the Farnsworth D15 [10,11,12]. The anomaloscope is considered as the gold standard for colour vision testing in clinical research [10,11].Both these tests also test blue yellow perception for which presently there are no guidelines in the IAF. With the increasing use of

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blue and majenta in the modern day cockpits blue yellow testing may assume great significance in the near future, hence this study also evaluated blue yellow colour perception among the candidates.

Material and Methods

Individuals reporting to a large medical evaluation centre of the IAF for medical examination for selection to military flying or for grant of commercial pilot's licence (CPL) over a period of 20 months were tested for colour perception with all four tests, after written informed consent. A group of controls consisting of colour normal experienced civil and military pilots were also evaluated with the 4 tests. Since the colour visions standards for selection are different for CPL and military flying in India, the subjects were grouped as below:

Test Group A (Military Pilots) -Current standard is a pass on Ishihara with no mistakes in reading the first 25 plates of the 38 plate Ishihara chart and pass on MLT by identifying correctly red, green and white light shown in pairs randomly through the smallest aperture of the Martin Lantern at 6 metres in a completely dark room, graded as Colour Perception standard One (CP-I).

Test Group B(CPL)- Current minimum standard is correct recognition of signal white ,green and red shown through the large aperture of Martin lantern at 1.5 m graded as CP-III or reads the requisite plates of Ishihara book as specified in IAF publication IAP 4303 4th edition para 2.11.24[9]. Those who fail are graded Colour Perception Standard IV (CP-IV), deemed unfit for selection.

Control Group A & B **-** Experienced colour normal Military Pilots and Airline Transport pilots less than 40 years of age. The age criterion of less than 40 years ensures a closer age match with the test population consisting of young individuals and minimises the effect of age related lenticular changes which can modify the spectrum of light reaching the fovea.

All participants underwent detailed ophthalmic examination including refraction, orthoptic evaluation, slit lamp and fundus examination. Individuals with best corrected binocular vision less than 6/6, media opacity in the pupillary area/visual axis, evidence of macular disease/optic nerve disease including glaucoma were excluded from the study.

Test Protocol

The test protocol for Ishihara and MLT was guided by the Manual for Medical Examination and Medical Boards IAP 4303 4thedn [9]. Participantswere tested with full spectacle corrections.

Ishihara Test **-** The 38 plate Pseudoisochromatic Chart (Kanehara& Co Japan) was used with the book held at 75 cm under daylight illumination allowing 4 s for each plate. When tested indoor, illumination used was fluorescent lamp with daylight filter.

Martin Lantern Test (MLT) **-**The original Martin Lantern manufactured by Kelvin Bottomley and Baird Ltd Glassgow was used for the tests. All subjects were tested at 6 metres. Those who made mistakes at 6 m were tested at 1.5 m also, but pass/fail recorded as per existing standard for each group.

Farnsworth D15 **-** The Farnsworth D15 manufactured by Richmond Inc USA with one reference and 15 coloured discsenclosed in plastic transparent case, was used for testing under fluorescent lamp with day light filter. Two or more major crossings on the scoring sheet were taken as an abnormal result.

Heidelberg Multi Colour Anomaloscope (HMC) -

The Heidelberg Multicolour Anomaloscope (HMC) Type 47700 manufactured by Oculus Optikgerate GmbH Germany was used for the tests (Fig-1). The equipment uses Rayleigh equation for red green matching as in the Nagels anomaloscope and Moreland for blue yellow. It has automatic neutral adaptation to minimise accommodation by presenting a white target intermittently. The default settings for anomaly quotient were: 0 to <0.7 protanomalous; 0.7 to 1.4 normal and >1.4 to infinity deuteranomalous. The equipment software has a rapid screening test, a manual test and specific test protocol. The test results and the diagnosis appear on the screen at the end. All participants underwent the screening and manual testing and specific test was done only in those found abnormal. After explaining the tests subjects were asked to get a clear focus by adjusting the eyepiece. The first test was rejected so as to familiarise the examinees to the tests. Then each eye was tested sequentially, dominant eye first. For the manual tests a minimum of five matches were obtained. Statistical analysis was done using SPSS version 8. P value for significance was taken as 0.05.

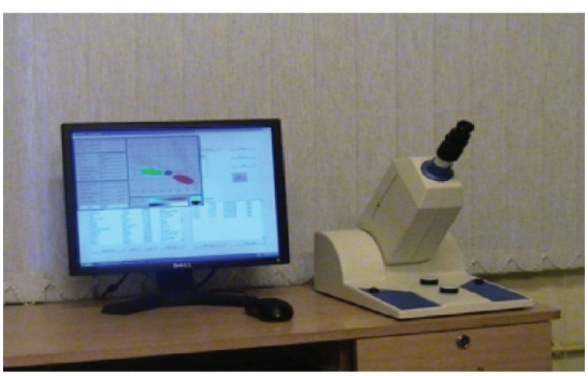

Figure 1: The Heidelberg Multicolour anomaloscope and the test screen .

Results

There were a total of 225 participants: - 115 in group A (102 males and 12 females) and 110 in group B (97 males and 13 females). The average age was 20.8 years (range 17-25) & 24.2 years (range 18-40) in Group A and B respectively. Control groups had 50 people each with an average age of 32.5 & 30.5 in group A & B respectively .The Group wise complete results are shown in table-1. Average testing time on HMC per individual for colour normals in Group A and B combined was 99.5 s and for those with deficient colour vision deficiency was 140.75 s and the difference was significant(P=0.03).

The comparison of the four tests in passing or failing the candidates in each group is presented in table-2. Similar result for fail/pass is seen in 79.1% and 88% in group A & B respectively which increases to 94% and 95% when MLT is disregarded, indicating that the MLT is at maximum variance. The agreement between Ishihara and HMC alone was 97%.

The comparative analysis of each test versus the HMC is shown in table-3.The McNemar test was used for statistical significance. The results show that, when the best results of each test is compared with HMC as in group A, only the Ishihara mirrors the HMC closely (P>0.05) while in group B where the passing standards on MLT and Ishihara are lower (CP-III) test results for all three were significantly different (P<0.05) from the HMC.

The sensitivity, specificity and the predictive value of each test as compared with the anomaloscope taken as the gold standard are presented in table-4. Consistent results for Ishihara and D15 in both groups were seen while the MLT results were different in the two groups. In group A it had the highest sensitivity and lowest specificity but in group B it had the poorest sensitivity as well as specificity among the three .It passed some of those failed by Ishihara (CP-IV) and D15. The overall accuracy was highest for the Ishihara and somewhat low for the MLT.

Table 1: Test results Group wise

	Total	Ishihara		MLT		D15		HMC	
		Normal	defective	Normal	defective	Normal	defective	Normal	Defective
Test Gp A	115	108 (CPII)	07 CPIII-04 CPIV-03	89 (CPI)	26 CPIII-21 CPIV-05	112	03 Protan-01 Deutan-02	115	10 Protan-02 Deutan-08
Test GpB	110	101 (CPII)	09 CPIII-03 CPIV-06	98	12 CPIII-10 CPIV-02	104	06 Protan 01 Deutan-05	98	12 Protan-01 Deutan-11
Total A+ B	225	209	16	187	38	216	09	203	22

Table 2: Comparison Pass and Fail Rates

	Total	All in Agreement	Differing results					
			Only MLT fail	Only MLT Pass	Only D15 pass	D15 & Ishihara Pass	Only HMC failed	Total
Gp A	115	91 (79.1%)	17	0	04	02	01	24
Gp B	110	97(88%)	03	04	0	0	06	13
A+ B	226	189	20	04	04	02	06	37

Table 3: Comparative analysis each test Vs HMC

Group A Variables	HMC Fail	HMC Pass	P value	Group B	HMC Fail	HMC Pass	P Value
Ishihara				Ishihara			
Fail	7 (70.0)	0 (0.0)	0.250	Fail	6 (50.0)	0 (0.0)	0.031
Pass	3 (30.0)	105 (100.0)		Pass	6 (50.0)	98 (100.0)	
MLT				MLT			
Fail	9 (90.0)	17 (16.2)	<0.00	Fail	2 (16.7)	3 (3.1)	0.029
Pass	1 (10.0)	88 (83.8)		Pass	10 (83.3)	95 (96.9)	
D15				D15			
Fail	3 (30.0)	0 (0.0)	0.016	Fail	6 (50.0)	0 (0.0)	0.031
Pass	7 (70.0)	105 (100.0)		Pass	6 (50.0)	98 (100.0)	

Table 4: Sensitivity, Specificity and Predictive value

	True +ve	True - ve	False +ve	False -ve	Sensi-tivity	Speci-ficity	PPV	NPV	Accuracy
Group A									
Ishihara	07	105	0	03	70%	100%	100%	97%	97%
MLT	09	88	17	01	90%	84%	35%	99%	84%
D15	03	105	0	07	30%	100%	100%	94%	94%
Group B									
Ishihara	06	98	0	06	50%	100%	100%	94%	95%
MLT	02	95	03	10	17 %	97%	40%	90%	88%
D15	06	98	0	06	50%	100%	100%	94%	95%

Table 5 : Comparative analysis of anomaly quotient

	Test A	Control A	Test B	Control B	Anomalous(A&B) All	CPIII	CPIV
Mean AQ	1.20	1.00	1.08	1.01	3.03	3.06	2.22
SD	0.92	0.10	0.49	0.09	2.79	0.57	1.37
Median	1.005	1.000	1.00	1.00	2.65	2.96	2.96
25,75 percentile	0.99.1.07	0.90,1.09	0.94,1.03	0.95,1.05	1.06,2.64	2.96,2.96	0.74,2.96
P Value	0.07 (Test Vs Control)		0.75 Test Vs Control		<0.001 Anomalous Vs Controls		0.408 CPIII Vs CPIV

Table 6: Clinical correlation of the Tests and the CP standards

Total No	Ishihara CPII	Ishihara CPIII	Ishihara CPIV	MLT CPI	MLT CPIII	MLT CPIV	D15 N	D15 Anom	HMC N	HMC Anom
MLT CPI187	187	0	0	187	0	0	187	0	186	1(AQ=0.4-1) Mild Protanomaly
Ishihara CPII209	209	0	0	187	21	0	209	0	203	06 03 Protanomaly 03 Deuteranomaly
Ishihara CPIII07	0	07	0	0	05	02	07	0	0	07Deuteranomaly
Ishihara CPIV09	0	0	09	0	05	04	0	09	0	09 06 Deuteranomaly 03 Deuteronopia
MLT CPIII31	20	05	06	0	31	0	26	05	19	12 10 Deuteranomaly 02 Deuternopia
MLT CPIV07	0	03	04	0	0	07	03	04	01	06 05 Deuteranomaly 01 Deuternopia

Table-5 shows the comparison of anomaly quotient (AQ).The AQ for the colour normals was taken as the average of all the values and for the anomalous the value farthest from the mean normal. Mann Whitney U test was used to compare medians. Anomaly quotient was significantly different only for the anomalous versus normal controls. For individuals found to be CP-III and CPIV by MLT and Ishihara there was no significant difference between the anomaly quotients of CP-III versus CP-IV.

Table-6 shows the results in terms of the CP classification currently followed in IAF. The following patterns could be discerned: All but one of the candidates (99.5%) declared MLT CPI (186/187) passed the HMC .The one who failed had only one match in each eye slightly outside range (0.4 Mild protanomaly). On the other hand 61.3% (19/31) of MLT-III and 14.3% (1/7) of MLT-IV also passed the anomaloscope. The corresponding anomaloscope pass rate for Ishihara CP-II, CP-III, and CP-IV is, 97 %, 0%, 0%. All MLT CP-I were normal on D15, 84% (26/31) of MLT-III were D15 normal and 16 % D15 fail, and 43 %(3/7) of MLT- IV passed D15 and 57% (4/7) failed D15. All Ishihara CP-II /CP-III passed the D15 test and

Table 7 : Blue Yellow HMC and D15

	HMC			D15	
	Normal	Indeterminate	Anomalous	Normal	Anomalous
Test Gp A	26(22.6%)	89 (60%)	0	115(100%)	0
Test Gp B	12(11.5%)	93(88%)	5(0.47%)	108((8.2%)	02(1.8%)
Total	38	187	5	223	02

all CP-IV failed the D15. The Farnsworth D15 passed candidates with CP-III or better on Ishihara (anomalous trichromats) and invariably failed those declared CPIV on Ishihara.

Test results for blue yellow perception are presented in table-7.The HMC did not give consistent results for blue yellow. Only 22.6% and 11.5% in Group A& B respectively had a perfect match. The D15 reported 2 out of the total 225 tested in both groups as tritanope who were also found abnormal on the anomaloscope.

Discussion

The Ishihara and the Martin lantern, the two tests currently recommended in India, have been compared with the Farnsworth D15 and the Heidelberg Anomaloscope (HMC), in terms of efficacy and level of agreement. HMC was taken as the gold standard. Majority of the earlier studies have been done on the Nagels anomaloscope [10, 11&13].

Unlike the Nagels, which is technically difficult to administer, the Heidelberg Multicolour Anomaloscope (HMC) is a microprocessor controlled computerised test based on same principle as Nagels, which is easy to understand.It generates results automatically, thus eliminating the need for a skilled technician. Our results show that the HMC enables comprehensive testing in a short time. The colour deficient participantstook a significantly longer time, but even in them, the average time was less than two and half minutes. Our study showed that there is no perfect agreement between the various tests in passing or failing the same individuals which is similar to the findings of Squire et al who compared three types of lanterns, the Ishihara and the anomaloscope [13]. However in our study, the correlation improved substantially when Martin Lantern Test (MLT) was disregarded. Comparison of each test with HMC reveals the best correlation with the Ishihara and the least with MLT which shows high sensitivity only in Group A, but at the cost of lower specificity. The sensitivity of Ishihara was rather low (70% in Group A and 50% in group B). Birch et al reported 98.7% sensitivity and 94.1% specificity for Ishihara compared to the Nagels anomaloscope using 471 colour normals and 401 colour deficient [14]. Ours was a smaller study with only 22 colour abnormal overall. In group B, the standards for civil aviation being lower allowedparticipants to pass with specified mistakes and hence a lower sensitivity was expected. Moreover our study design was different in the sense that we tested actual aspiring aviators whose colour perception status was not known prior to testing. Despite random presentation of plates, passing by memorisation by candidates who have practised the test in order to get selected, could not be ruled out completely. Nevertheless, it is safe to conclude that though the overall results suggest that Ishihara matched the HMC closely, it allowed some HMC abnormals to pass even when a strict criterion of no mistakes was used. The D15 had the poorest sensitivity amongst the three but it was 100% specific. The D15 consistently passed individuals classified CP-III by Ishihara and failed those who were CP-IV indicating that the D15 failed only individuals with severe defects. This was on expected lines as studies that have evaluated the D15 have shown that it effectively detected only the severely anomalous trichromats and the dichromats while mild to moderate anomalous trichromatswere likely to pass this test [15, 16].

The study results showed the overall accuracy and reliability of the MLT was questionable especially when testing was done at 1.5 m. The Martin Lantern is of 1939 vintage initially designed to simulate the lights of a ship in different weather conditions [17]. As an occupational screening test in aviation there are no studies validating the MLT. The lanterns which are being used more commonly and for which operational trials are available are the Farnsworth, the Holmes Wright and the Beynes lanterns [3]. Studies evaluating these lantern tests have noted many disparities and conflicting results [13, 18, 19, 20&21]. When MLT was eliminated we found that the level of correlation between the other three tests became high and much more acceptable. The study highlights the lacunae in using functional tests such as the MLT in its existing form, as the sole or final test for colour vision deficiency. The results of MLT should be read in conjunction with other diagnostic tests for colour vision such as the anomaloscope and the Farnsworth D15 and hence a review of the existing protocols for testing colour vision in the IAF is suggested, which should include these diagnostic tests.

For blue yellow colour vision the study showed widely varying results with the anomaloscope. Blue yellow colour perception can vary in normal population due to physiological variations in macular pigment densities and lens density, which selectively absorbs the lower wavelengths [22, 23]. A study designed specifically for blue yellow colour vision testing which takes into account these variations, may be able to give better results. An abnormal result on the Farnsworth D15 usually indicates a severe defect in blue yellow perception [24]. However, for formulating guidelines for blue yellow screening the results of present study were insufficient.

Conclusion

There is a need to supplement the existing colour vision tests for military pilots in India, with more objective, diagnostic tests such as the anomaloscope. Since this was the first study in the Indian Armed Forces on this kind of equipment, it needs to be replicated across all major medical evaluation centres and service hospitals as part of a multicenter trial.

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