



THE CONE CONTRAST TEST: Normative Scores for Binocular Testing



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Outline

- ***Purpose***
- ***Background***
- ***Literature Review***
- ***Methods***
- ***Findings***
- ***Discussion***
- ***Recommendations***
- ***References***





Background

- **Cone Contrast Test (CCT)**
 - *Primary color vision screening for US Air Force aviators and aviator applicants*
 - *Computer-based test using color and contrast*
 - *Selectively stimulates each of the three cone types (red, green, and blue) in the retina*
 - *Letters presented on a gray background decreasing in contrast until a threshold is reached*
 - *The USAF administers the test monocularly*
 - *Passing score is 75 or above for each eye*



Cone Contrast Test

Score	Cone Contrast Test			Cone Contrast (%)		
	L Cone	M Cone	S Cone	L, M	S	
10	V Z	N F	E Z	27.5	173	↑ severe ↓ Color deficiency ↓ mild ↓ Normal color vision ↓
20	F V	Z U	N R	19.1	120	
30	R P	E P	F D	13.2	83	
40	Z E	N F	Z V	9.1	57	
50	H R	E D	R P	6.3	39	
60	D R	N P	Z H	4.4	27	
70	N Z	D U	E D	3.0	19	
80	H V	E N	V H	2.1	13	
90	E R	N P	F E	1.4	10	
100				1.0	7	

Letters seen only by red, green or blue cones.

Higher the score, the better the color vision.

Red CVD fails red test,
Green CVD fails green.



Purpose & Hypothesis

- ***Purpose: Establish normative occupational values for the CCT when administered under binocular conditions***
- ***Hypothesis: Monocular CCT pass/fail values can not be used for binocular test administration. Binocular normative values are expected to be higher than monocular values.***



Literature Review

- ***Binocular viewing enhances visual function***
 - ***Previous study showed mean binocular CCT score increased 38% above monocular CCT (Rabin, et al)***
 - ***Binocular occupational task performance improved 20.4% to 29.5% (Sheedy, et al)***
- ***Color vision tests are designed and validated for specific viewing conditions (binocular vs. monocular)***



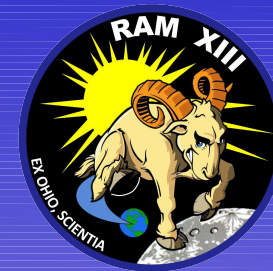
Color Vision Tests

Monocular

- ***Nagel Anomaloscope
(Gold standard for color
vision testing)***
- ***Pseudoisochromatic
Plates (PIP1 and PIP2)***
- ***CCT***

Binocular

- ***Colour Assessment and
Diagnosis (CAD) Test***
- ***Computerized Color
Vision Test (CCVT)***
- ***PAPI Signal Light Test***
- ***Aviation Lights Test***



Methods

- ***Retrospective study using data obtained from the USAF Aeromedical Consultation Service Ophthalmology Branch***
- ***Ensured best visual acuity for each subject (20/20)***
- ***142 subjects tested under monocular and binocular conditions***
 - ***111 Color Vision Normal (CVN) and 31 congenital (red/green) Color Vision Deficient (CVD) subjects included***
 - ***Score based on average of right/left scores for monocular test and average of 2 binocular test trials***
- ***Anomaloscope used to confirm CVD subjects***



Results: Color Vision Normal

	Monocular		Binocular		% increase	
	Red Cone	Green Cone	Red Cone	Green Cone	Red	Green
Mean (SD)	97.95 (4.37)	97.5 (3.84)	99.89 * (0.62)	99.66 * (0.98)	2%**	2%**
Minimum	65	77.5	95	95		
Maximum	100	100	100	100		
95% CI	97.13-98.32	96.78 - 98.22	99.77 - 100.01	99.48 - 99.84		

n = 111 subjects

* $p < 0.001$ vs. monocular score (Wilcoxon Signed Rank Test)

** Ceiling effect



Results: Color Vision Deficient

	Monocular		Binocular		% increase	
	Protan (Red Cone)	Deutan (Green Cone)	Protan (Red Cone)	Deutan (Green Cone)	Protan	Deutan
Mean (SD)	30.42 (25.17)	56.60 (9.68)	47.90 * (15.92)	64.90 ** (13.63)	57%	15%
Minimum	0	35	22.5	40		
Maximum	60	72.5	65	92.5		
95% CI	4.01 - 56.83	52.60 - 60.60	31.19 - 64.61	59.28 - 70.52		

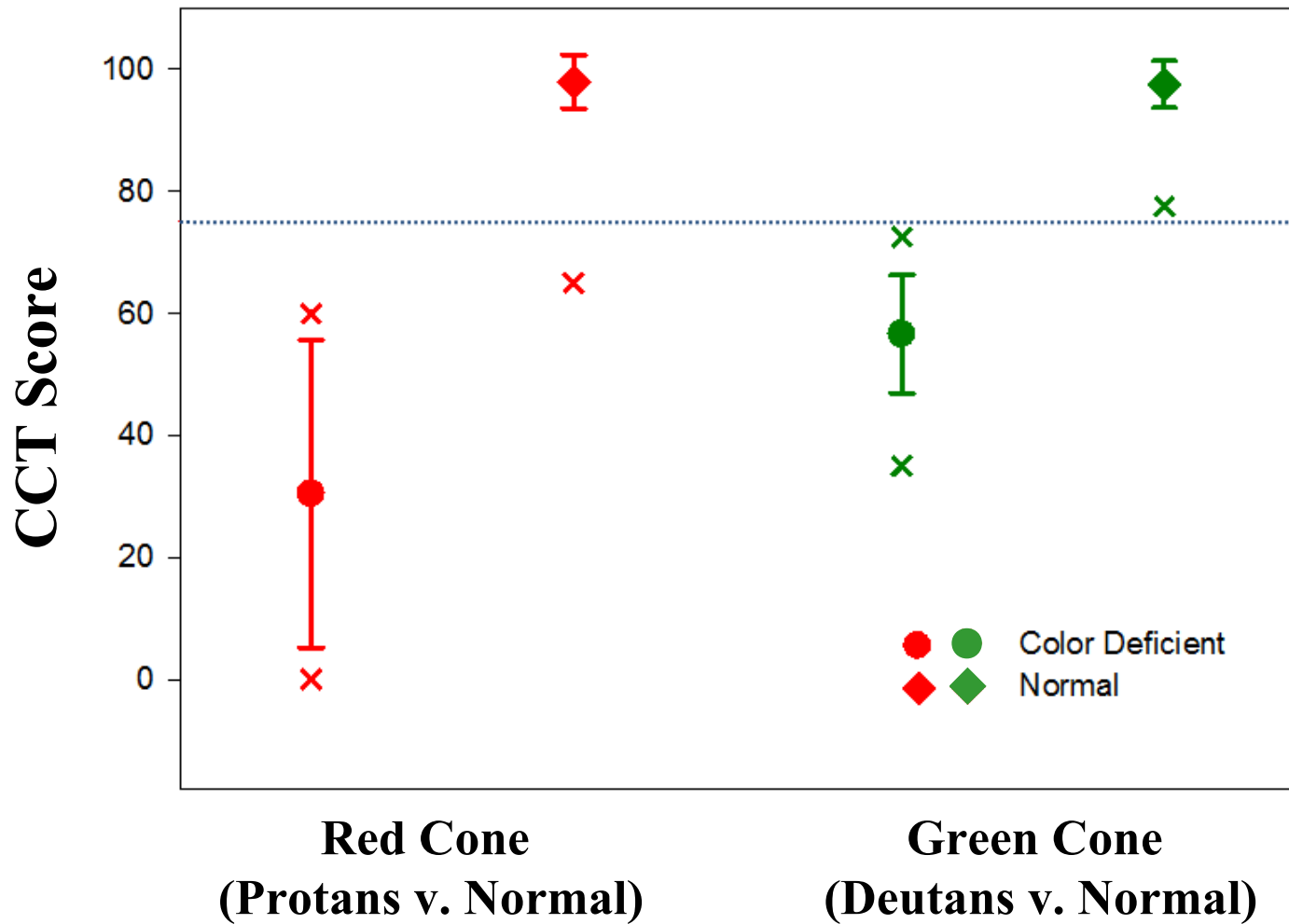
n = 25 deutan, 6 protan

* $p < 0.05$ vs. monocular score (Wilcoxon Signed-Rank Test)

** $p < .001$ vs. monocular score (Wilcoxon Signed-Rank Test)

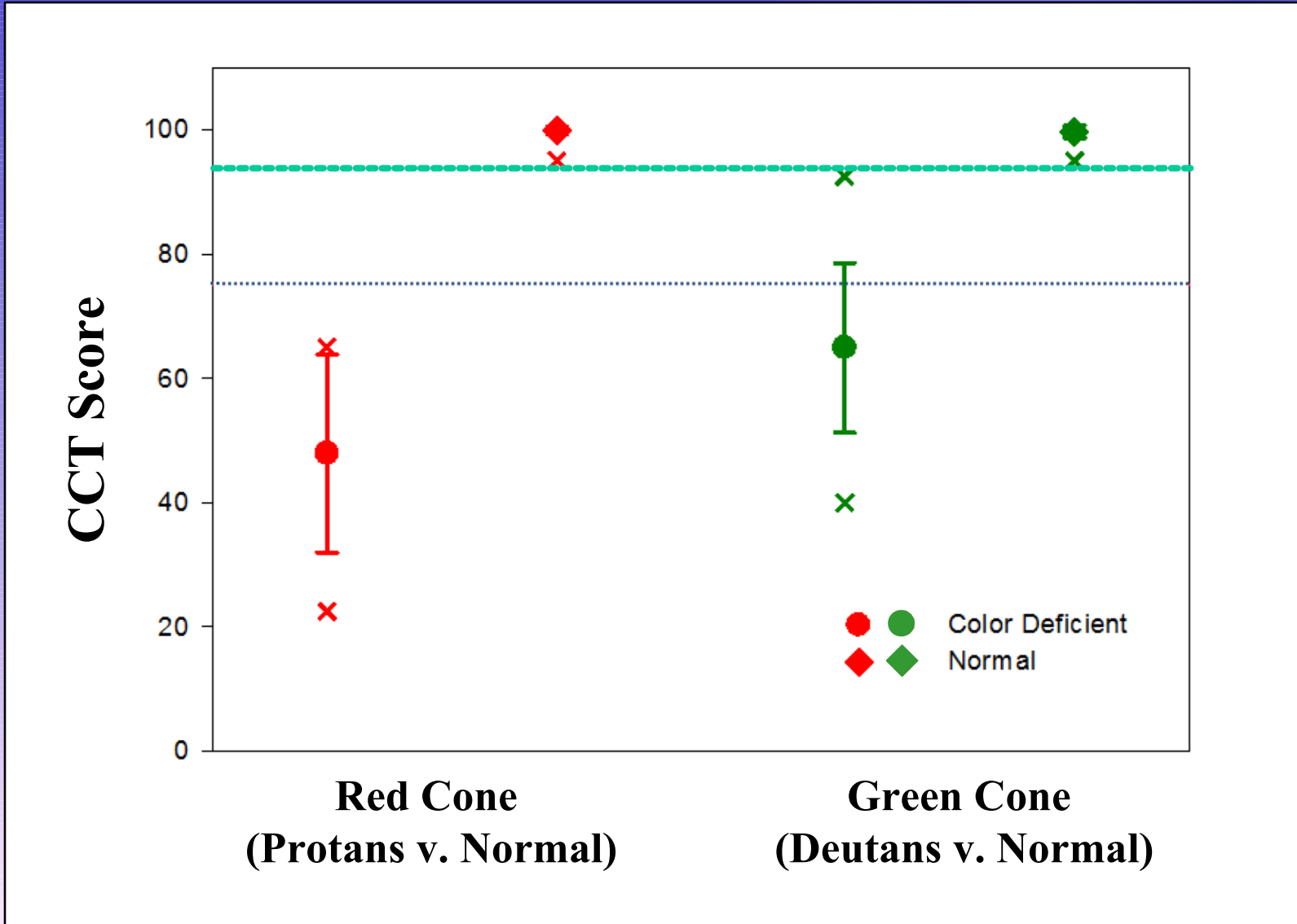
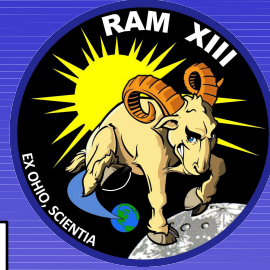


Findings: CVD vs. CVN (Monocular)





Findings: CVD vs. CVN (Binocular)





Findings: Proposed Normative Values



Passing Scores	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Monocular (≥ 75)	1.00	0.99	0.97	1.00
Binocular (≥ 75)	0.84	1.00	1.00	0.96
Binocular (≥ 93)	1.00	1.00	1.00	1.00



Limitations

- ***No blue cone (tritan) or acquired deficiencies included***
- ***Ceiling effect of current test set up for binocular viewing among CVN subjects***
 - ***Not accurately measuring the normal threshold level***
- ***Small sample size of CVD subjects***
- ***This is a preliminary study to look at normative scores under binocular conditions***



Discussion

- ***Color contrast sensitivity is improved with binocular viewing***
 - ***Increased binocular test scores statistically significant for both CVN and CVD subjects***
- ***A binocular normative score of 93 achieves 100% sensitivity and specificity***
- ***Current monocular pass / fail criteria for the CCT not valid for binocular conditions***



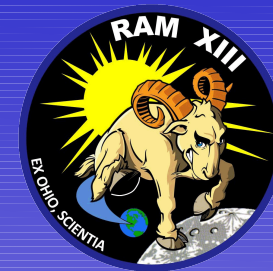
Discussion

- ***Advantages for binocular testing***
 - ***Faster testing***
 - ***Reproduces “real world” visual conditions***
 - ***Enables better correlation within operational performance studies***
- ***Disadvantages***
 - ***Potential to miss unilateral/asymmetric CVD (i.e. acquired)***
 - ***Reduced ability to intervene early in acquired ocular disease***
 - ***Cannot apply current validated monocular pass/fail criteria to binocular testing conditions***



Recommendations

- ***Perform further research to correlate CCT binocular score with occupational visual performance***
- ***Reprogram and validate CCT to test binocularly***
 - ***Decrease contrast level to reach threshold for CVNs***
- ***Increase sample size, specifically CVDs***



References

1. **Evans S. Colour assessment and diagnosis (CAD) test. Proceedings of the CMOs Forum 2009 June. Civil Aviation Authority, United Kingdom.**
 2. **Milburn N, Mertens H. Predictive validity of the aviation lights test for testing pilots with color vision deficiencies. Washington, DC; U.S. Department of Transportation, Federal Aviation Administration; 2004 Sep. Report No: DOT/FAA/AM-04/14.**
 3. **Picken D, Mann M, Rings M. Preliminary Validation of a computerized color vision test. Naval Aerospace Medical Institute, Pensacola FL.**
 4. **Rabin J, et al. Binocular enhancement of color contrast sensitivity. Proceedings of the Association for Research in Vision and Ophthalmology. Program No: 6398.**
 5. **Rabin J, Gooch J, Ivan D, Harvey R, Aaron M. Beyond 20/20: New clinical methods to quantify vision performance. Military Medicine 2011; 176(3):324-326.**
 6. **Rabin J, Gooch J, Ivan D. Rapid quantification of color vision: the cone contrast test. Investigative Ophthalmology & Visual Science 2011; 52(2):816-820.**
 7. **Rabin J. Cone-specific measures of human color vision. Investigative Ophthalmology & Visual Science 1996; 37(13):2771-2774.**
 8. **Rabin J. Quantification of color vision with cone contrast sensitivity. Visual Neuroscience 2004; 21:483-485.**
 9. **Sheedy JE, Bailey IL, Buri M, Bass E. Binocular vs. monocular task performance. American Journal of Optometry & Physiological Optics 1986; 63(10): 839-846.**
- Wright S. Development of the cone contrast test. Proceedings of the Aeromedical Consultation Service 2012 Aug. United States Air Force School of Aerospace Medicine, Wright Patterson AFB, OH. http://www.flcmidwest.org/2012regionalmeeting/presentations/Steve-Wright_Cone-Contrast-Test.pdf**



Questions?



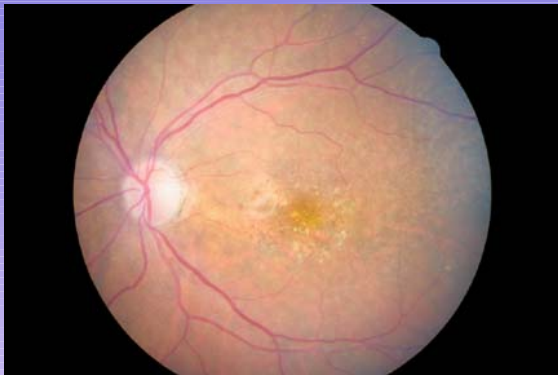


Acquired Color Deficiency



- **Acquired blue cone loss occurs early in eye disease**

Macular Degeneration



Diabetes



Glaucoma



- **Making blue cone tests necessary**

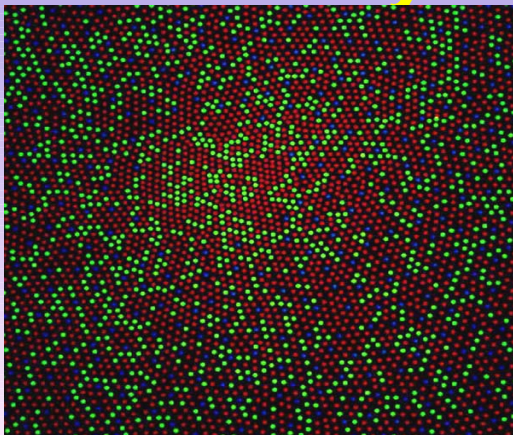


Acquired Color Deficiency



- **Secondary to disease, trauma or toxicity.**
- **Often unilateral, or asymmetric between eyes.**
 - **Unstable and variable in course.**
- **Red-green or blue-yellow; usually blue-yellow.**

Why blue acquired deficiency?



- **Very few blue cones...**
- **Lack of redundancy.**
- **Small amount of damage has large effect.**