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

<table>
<thead>
<tr>
<th>Score</th>
<th>L Cone</th>
<th>M Cone</th>
<th>S Cone</th>
<th>L, M</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>V</td>
<td>Z</td>
<td>N</td>
<td>F</td>
<td>E</td>
</tr>
<tr>
<td>20</td>
<td>F</td>
<td>V</td>
<td>Z</td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td>30</td>
<td>R</td>
<td>P</td>
<td>E</td>
<td>P</td>
<td>F</td>
</tr>
<tr>
<td>40</td>
<td>Z</td>
<td>E</td>
<td>N</td>
<td>P</td>
<td>Z</td>
</tr>
<tr>
<td>50</td>
<td>H</td>
<td>R</td>
<td>E</td>
<td>D</td>
<td>R</td>
</tr>
<tr>
<td>60</td>
<td>D</td>
<td>R</td>
<td>H</td>
<td>N</td>
<td>Z</td>
</tr>
<tr>
<td>70</td>
<td>N</td>
<td>Z</td>
<td>D</td>
<td>U</td>
<td>E</td>
</tr>
<tr>
<td>80</td>
<td>I</td>
<td>F</td>
<td>E</td>
<td>H</td>
<td>V</td>
</tr>
<tr>
<td>90</td>
<td>G</td>
<td>R</td>
<td>I</td>
<td>H</td>
<td>F</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Letters seen only by red, green or blue cones.**

- **Severe** Color deficiency
- **Mild** Color deficiency
- **Normal color vision**

**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

<table>
<thead>
<tr>
<th></th>
<th>Monocular</th>
<th>Binocular</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red Cone</td>
<td>Green Cone</td>
<td>Red Cone</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>97.95 (4.37)</td>
<td>97.5 (3.84)</td>
<td>99.89 (0.62)</td>
</tr>
<tr>
<td>Minimum</td>
<td>65</td>
<td>77.5</td>
<td>95</td>
</tr>
<tr>
<td>Maximum</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>95% CI</td>
<td>97.13-98.32</td>
<td>96.78 - 98.22</td>
<td>99.77 - 100.01</td>
</tr>
</tbody>
</table>

n = 111 subjects

* p < 0.001 vs. monocular score (Wilcoxon Signed Rank Test)
** Ceiling effect
### Results: Color Vision Deficient

<table>
<thead>
<tr>
<th></th>
<th>Monocular</th>
<th>Binocular</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protan (Red Cone)</td>
<td>Deutan (Green Cone)</td>
<td>Protan (Red Cone)</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>30.42 (25.17)</td>
<td>56.60 (9.68)</td>
<td>47.90 *</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>35</td>
<td>22.5</td>
</tr>
<tr>
<td>Maximum</td>
<td>60</td>
<td>72.5</td>
<td>65</td>
</tr>
<tr>
<td>95% CI</td>
<td>4.01 - 56.83</td>
<td>52.60 - 60.60</td>
<td>31.19 - 64.61</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Passing Scores</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocular (&gt;=75)</td>
<td>1.00</td>
<td>0.99</td>
<td>0.97</td>
<td>1.00</td>
</tr>
<tr>
<td>Binocular (&gt;=75)</td>
<td>0.84</td>
<td>1.00</td>
<td>1.00</td>
<td>0.96</td>
</tr>
<tr>
<td>Binocular (&gt;=93)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
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


3. Picken D, Mann M, Rings M. Preliminary Validation of a computerized color vision test. Naval Aerospace Medical Institute, Pensacola FL.


Questions?
Acquired Color Deficiency

- Acquired blue cone loss occurs early in eye disease

- 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.