The US Army
Color Vision Study

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- The opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the U.S. Army and/or the Department of Defense
Objectives

- Describe the effectiveness (i.e., sensitivity and specificity) of commercially available color vision tests, using the anomaloscope as the “gold standard” to classify the color vision
- Compare the administration time of computerized color vision tests
- The ultimate goal is to provide recommendations for a color vision test that is quick to administer, easy to interpret, and able to accurately classify and quantify color deficiencies.
Facts

• Color vision deficiency is a common disqualifying factor for certain occupations in the U.S. Army
  - No more than 2 errors on the Dvorine PIP test
  - Or no mistakes on Farnsworth Lantern (one run)

• Tactical displays use color coding as a friend/foe discriminator, which stresses the importance of normal color discrimination.

• New display technologies demand that personnel color vision standards remain task relevant.
Methods

- Research Conducted at Carl R. Darnall Army Medical Center (CRDAMC), Fort Hood, TX
- 91 U.S. military personnel subjects
  - 46 (92 eyes) Color Vision Normal (CVN)
    - Age: 33.64 ± 10.66
    - Average High Contrast Visual Acuity: OD 20/20; OS 20/20
    - Average Low Contrast Visual Acuity: OD 20/39; OS 20/37
  - 45 (90 eyes) Color Vision Deficient
    - Age: 31.22 ± 9.44
    - Average High Contrast Visual Acuity: OD 20/20; OS 20/20
    - Average Low Contrast Visual Acuity: OD 20/37; OS 20/38
Methods

• 45 (90 eyes) Color Vision Deficient
  – 31 deutan
    • 7 deuteranopes
    • 24 deuteranomalous
  – 14 protan
    • 9 protanopes
    • 5 protanomalous
Methods

• Color Vision Test Battery
  – Dvorine Pseudoisochromatic Plates (PIP)*
  – Standard PIP 2 (SPP2)*
  – PIP Ishihara Compatible (PIPIC)*
  – Hardy Rand and Ritter (HRR) PIP, 4th Edition*
  – Farnsworth Lantern (FALANT)
  – Farnsworth D-15 (D15)*
  – Colour Assessment & Diagnosis (CAD) test
  – Cone Contrast Test (CCT)
• Tests were administered monocularly following the manufacturer’s instructions
• Binocular administration time was recorded for plate tests

*Using Richmond Tru-Daylight Illuminator
## Methods

### Failure Criteria

<table>
<thead>
<tr>
<th>Test</th>
<th>Failure Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIP</td>
<td>Missing 3 or more plates out of 14 plates</td>
</tr>
<tr>
<td>SPP2</td>
<td>Missing 2 or more plates out of 10 plates</td>
</tr>
<tr>
<td>PIPC</td>
<td>Missing 3 or more plates out of the first 14 plates</td>
</tr>
<tr>
<td>HRR</td>
<td>Any error in plates #5 to #10</td>
</tr>
<tr>
<td>FALANT</td>
<td>Any error in one run</td>
</tr>
<tr>
<td>D15</td>
<td>Any crossing line parallel to the protan, deutan, or tritan reference lines</td>
</tr>
<tr>
<td>CAD (R/G)</td>
<td>Deficiency as indicated by the instrument</td>
</tr>
<tr>
<td>CCT</td>
<td>Score lower than 75 for protan, deutan, or tritan</td>
</tr>
</tbody>
</table>
Methods

• Results presented as:
  – Sensitivity: The probability that the test identifies a person as color deficient when that person is really color deficient; i.e., the probability of failing the test given color deficiency:

        Sensitivity = P(fail test | color deficient)

  – Specificity: The probability that the test identifies a person as color normal when it fact that person is really color normal; i.e., the probability of passing the test given color normalcy:

        Specificity = P(pass test | color normal)
### Results

<table>
<thead>
<tr>
<th></th>
<th>PIP</th>
<th>SPP2</th>
<th>PIPC</th>
<th>HRR</th>
<th>FALANT</th>
<th>D15</th>
<th>CAD R/G</th>
<th>CCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE Sensitivity</td>
<td>1.00</td>
<td>0.89</td>
<td>1.00</td>
<td>0.96</td>
<td>0.96</td>
<td>0.41</td>
<td>1.00</td>
<td>0.98</td>
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<tr>
<td>LE Sensitivity</td>
<td>0.98</td>
<td>0.89</td>
<td>1.00</td>
<td>0.96</td>
<td>0.91</td>
<td>0.42</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>RE Specificity</td>
<td>0.96</td>
<td>1.00</td>
<td>0.98</td>
<td>0.94</td>
<td>0.96</td>
<td>1.00</td>
<td>0.54</td>
<td>1.00</td>
</tr>
<tr>
<td>LE Specificity</td>
<td>0.96</td>
<td>1.00</td>
<td>1.00</td>
<td>0.98</td>
<td>0.96</td>
<td>1.00</td>
<td>0.72</td>
<td>1.00</td>
</tr>
<tr>
<td>Mean Adm Time (min)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>14</td>
<td>6</td>
</tr>
</tbody>
</table>

Konan notes: PIPC = ColorDx Standard PIP 24
Discussion

- The high sensitivity and specificity of PIP-type test stress the need for appropriate illumination source when performing color vision screening
- D15 Sensitivity = 0.41
- The D in D-15 stands for dichotomous, differentiating moderate/severe from mild color deficiency; hence, the D-15 intentionally passes individuals with mild color deficiency, individuals the other tests identify.
Conclusions

• The PIPC and CCT have the highest combined sensitivity and specificity as screening tests for color vision.
  – PIPC has marginally higher sensitivity (1 vs 0.99) and shorter administration time (3 vs 6 min)
  – CCT has marginally higher specificity (1 vs 0.99), but takes twice as long to administer.

Konan notes:
PIPC = ColorDx Standard PIP 24 has exceptional performance for color vision screening
Questions?