Assessment of Color Vision Screening Tests for U.S. Navy Special Duty Occupations

M. Reddix¹, CDR, USN, PhD
C. Kirkendall¹, PhD
H. Gao¹, LCDR, USN, OD, PhD
K. O'Donnell², PhD
H. Williams¹, PhD
S. Eggan¹, LT, USN, PhD
W. Wells¹ LCDR, USN, PhD

¹Naval Medical Research Unit Dayton, Wright–Patterson AFB, Ohio
²United States Air Force Academy, Colorado Springs, Colorado

2014 AsMA 85th Annual Scientific Meeting, San Diego, CA
Legal Notifications

- **Distribution**
  - Approved for public release; distribution is unlimited.

- **Source of Support**
  - This work was funded by the Advanced Medical Development Program, BUMED, US Navy.

- **Human Research Protections**
  - This study protocol was approved by the Naval Medical Research Unit Dayton Institutional Review Board in compliance with all Federal regulations governing the protection of human subjects.

- **Disclaimer**
  - The views expressed are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, nor the US Government.
  - The authors have no financial relationships to disclose.
  - The authors will not discuss off-label use and/or investigational use in the presentation.

- **Copyright**
  - The authors are military service members or employees of the U.S. Government. This work was prepared as part of official duties. Title 17, USC, §105 provides that ‘Copyright protection under this title is not available for any work of the U.S. Government.’ Title 17, USC, §101 defines a U.S. Government work as a work prepared by a military service member or employee of the U.S. Government as part of that person’s official duties.
Objectives

- Compare the diagnoses of two current and four proposed color vision tests (CVTs) to the HMC–RT anomaloscope

- Use a signal detection model to assess the sensitivity of each test

- Assess the degree to which the severity of a color–vision deficiency (CVD) affects human performance in aviation–related tasks
The HMC-RT anomaloscope was used to determine color-normal and color-deficient (CVDs) participants, as well as to classify the type of color deficiency; monocular administration.
Method
Current USN aviation color–vision selection standards

Ishihara Pseudo–isochromatic Plates (PIP)
- 24-plate version (plates 2–15)
- USN passing criteria:
  - Must correctly identify at least 12/14 plates

Optec–900
- FALANT equivalent
- USN passing criteria:
  - Must correctly identify 9/9 or 16/18 presentations
Colour Assessment and Diagnosis test (CAD)
- Manufacturer passing criteria:
  - Fast CAD: 100% correct
  - Full CAD:
    - Protan-like: Varies by age
    - Deutan-like: Varies by age

Cone Contrast Test (CCT)
- USAF passing criteria:
  - ≥ 75 for each section of the test (red, green, and blue)
  - Monocular administration

Waggoner Computerized Color Vision Test (WCCVT)
- Manufacturer passing criteria:
  - Screening section: ≥ 22/26
  - Protan section: ≥ 28/32
  - Deutan section: ≥ 28/32
  - Tritan section: ≥ 10/12
Method
Participants and procedures

- **Participant population**
  - 191 participants from USAFA, NAMI, NMOTC, and Naval Hospital Pensacola
  - Age range: 18–35
  - 17% female

- **Procedures**
  - All subjects completed anomaloscope first
  - Other CVTs were administered in counterbalanced order
Results
Color-vision classification by HMC–RT anomaloscope
Results
CVT performance

Color-vision diagnoses for each test

Number of participants diagnosed as color-normal by anomaloscope (133)
Number of participants diagnosed as color-deficient by anomaloscope (58)

<table>
<thead>
<tr>
<th>Test</th>
<th>Number of Participants Diagnosed as Color-normal</th>
<th>Number of Participants Diagnosed as Color-deficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIP</td>
<td>133</td>
<td>40</td>
</tr>
<tr>
<td>Optec</td>
<td>140</td>
<td>58</td>
</tr>
<tr>
<td>Fast CAD</td>
<td>140</td>
<td>56</td>
</tr>
<tr>
<td>Full CAD</td>
<td>140</td>
<td>56</td>
</tr>
<tr>
<td>CCT</td>
<td>140</td>
<td>56</td>
</tr>
<tr>
<td>WCCVT</td>
<td>140</td>
<td>56</td>
</tr>
</tbody>
</table>
Results

CVT performance

Graphical representation of test performance
Results
CVT performance

Graphical representation of test performance

Probability of a false alarm

Probability of a hit

Optec

PIP

Fast CAD

Full CAD

WCCVT

CCT
Method

Development of aviation-related reaction time tasks

- Relate CVD type and severity to human performance
  - Out-of-cockpit color discrimination reaction time task
    - Precision Approach Path Indicator (PAPI)
    - FAA aviation red and white
  - In-cockpit display icon discrimination reaction time task
    - F/A-18E/F AMPCD glass cockpit colors (red, yellow, and green)
  - Tests were administered in counterbalanced order
Method

PAPI color-discrimination reaction time test

Simulated 1 NM view

<table>
<thead>
<tr>
<th>Low</th>
<th>On</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔️️</td>
<td>✔️️️</td>
<td>✔️️️</td>
</tr>
</tbody>
</table>

PAPI lights
Method
Display icon color-discrimination reaction time test
Results
PAPI task

Main effect of color-vision deficiency severity on accuracy (p-values)

<table>
<thead>
<tr>
<th></th>
<th>Color-normal</th>
<th>Mild Deutan</th>
<th>Moderate Deutan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Deutan</td>
<td>0.995</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Deutan</td>
<td>0.973</td>
<td>0.999</td>
<td></td>
</tr>
<tr>
<td>Severe Deutan</td>
<td>0.079</td>
<td>0.170</td>
<td>0.148</td>
</tr>
</tbody>
</table>

Main effect of color-vision deficiency severity on reaction time (p-values)

<table>
<thead>
<tr>
<th></th>
<th>Color-normal</th>
<th>Mild Deutan</th>
<th>Moderate Deutan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Deutan</td>
<td>0.760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Deutan</td>
<td>0.000</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Severe Deutan</td>
<td>0.002</td>
<td>0.051</td>
<td>0.460</td>
</tr>
</tbody>
</table>

Mean reaction time
PAPI indication
Above On Below
Mean reaction time (ms)

Mean number of errors per subject
PAPI indication
Above On Below
Results
Display icon task

Main effect of color-vision deficiency severity on accuracy (p-values)

<table>
<thead>
<tr>
<th></th>
<th>Color-normal</th>
<th>Mild Deutan</th>
<th>Moderate Deutan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Deutan</td>
<td>0.905</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Deutan</td>
<td>0.000</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Severe Deutan</td>
<td>0.000</td>
<td>0.000</td>
<td>0.065</td>
</tr>
</tbody>
</table>

Main effect of color-vision deficiency severity on reaction time (p-values)

<table>
<thead>
<tr>
<th></th>
<th>Color-normal</th>
<th>Mild Deutan</th>
<th>Moderate Deutan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Deutan</td>
<td>0.039</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Deutan</td>
<td>0.000</td>
<td>0.169</td>
<td></td>
</tr>
<tr>
<td>Severe Deutan</td>
<td>0.000</td>
<td>0.042</td>
<td>0.862</td>
</tr>
</tbody>
</table>
From the US Navy perspective is the Optec/FALANT still valid?

- Official US Navy color vision test in 1954 to: “salvage those persons with a mild color vision defect who are not considered dangerous to Naval service”
- 14 subjects failed the PIP, but passed the Optec

<table>
<thead>
<tr>
<th>Classification</th>
<th>Subjects (n)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal*</td>
<td>5</td>
<td>36%</td>
</tr>
<tr>
<td>Mild*</td>
<td>6</td>
<td>43%</td>
</tr>
<tr>
<td>Deutan*</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Moderate*</td>
<td>2</td>
<td>14%</td>
</tr>
<tr>
<td>Severe*</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Protan*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total Subjects</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

*Classification based on USAF standard (CCT). Score ranges: normal 75–100; mild 55–70; moderate 35–50; severe 0–30
Optec performance
Reaction time task performance

Accuracy

Mean Accuracy (%)

Failed PIP/Passed Optec
Color-normal

Display icon task
PAPI task

Reaction Time

Mean Reaction Time (msec)

Display icon task*  * p < 0.001
PAPI task
Computerized color–vision tests (CAD, CCT, WCCVT) have near equal sensitivity (d’).

Glass cockpit color palette is likely to produce decrements in human performance for mild CVDs.
- PIP + Optec screening criterion may be too liberal.

Should selection standards development be tied to human performance metrics? If so, ideal test would have:
- Valid sensitivity & specificity across a wide area of CIE color space
- Severity scales that predictably relate to human performance
  - Severity scales offer greater flexibility for setting selection standards suitable for specific special duty occupations.
Questions?

Contact Information:
Naval Medical Research Unit Dayton
2624 Q Street, Bldg. 851, Area B
Wright-Patterson AFB, OH 45433
Phone: 937–938–3892
Email: michael.reddix@us.af.mil