Color Vision in Heterozygous Carriers of Color Deficiency

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Disclosure Information

Speaker: Andrew Yoder

I have no financial relationships to disclose.
I will not discuss off-label use and/or investigational use in my presentation.
Normal Color Vision

- Normal color vision
- Based on red, green and blue sensitive retinal cones

Adaptive optics image of human retina

http://vision.berkeley.edu/nordalab/aos Tec.htm

Red
Blue
Green

WAVELENGTH (nm)

400 500 600 700
Color Vision Deficiency (CVD)

- Hereditary CVD
  - 8% of males
  - 1 in 200 females
- Due to a shift in cone sensitivity, or
- Lack of red or green cones
Hereditary blue cone deficiency is quite rare.

But Red, Green &/or Blue deficiency can occur as an early sign of disease.
CVD Limits Performance & Safety

- CVD can decrease **performance & threaten safety** on real-world tasks
- CVDs can show increased
  - Response time for critical tasks
  - Error rate
  - Fatigue, stress
  & limited cues
- Exacerbates CVD

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**Colorblindness link to crash studied**

TALLAHASSEE, Fla. — A FedEx plane crash last year may have been caused by a colorblind co-pilot’s difficulty in seeing red warning lights, federal investigators say.

The National Transportation Safety Board is investigating whether William Frye failed to see red runway lights that indicated the cargo jet was dangerously low, the St. Petersburg Times reported Friday.

The Boeing 727 crashed and burned a half-mile short of the runway at the Tallahassee airport in July 2002 as it was coming in for a landing from Memphis, Tenn. Its three-member crew escaped serious injury. The crash destroyed last-minute qualifying paperwork for several Florida legislative races.

— Compiled from wire reports
Carriers of Color Deficiency

- Red (protan) and green (deutan) CVD are X-chromosome linked conditions.
- Gene for CVD is on X-chromosome.
- CVD is passed from Mom to Son.
- Daughter acquires CVD from Mom and Dad.
Carriers of Color Deficiency

- Heterozygous carriers of CVD (e.g., daughter of CVD father) typically pass standard color tests.
- Some carriers show mild CVD…
- Which is likely due to expression of CVD cone along with the three normal cones.
Our purpose was to evaluate color vision in obligate carriers of hereditary color vision deficiency.
Subjects and Color Tests

- Battery of color tests conducted on
  - 16 color vision normals (CVN)
  - 9 female carriers based on family history &/or testing of family members
Color Vision Tests

- Color tests included
  - Pseudo-isochromatic plates (PIP)
    - Ishihara
    - Dvorine
    - HRR
Color Vision Tests

- Color ordering tests
- Normal and de-saturated D15

![Normal D-15 vs De-saturated](image)

- FM 100 Hue

![FM 100 Hue](image)
### Cone Contrast Test Principles

**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>
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<td>N F</td>
<td>E Z</td>
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<td>N R</td>
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<td>E P</td>
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<td>F H</td>
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<td>90</td>
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<td>R E</td>
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</tbody>
</table>

**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.
Cone Contrast Test (CCT)

- Letters visible to red, green or blue cones
- Single colored letter appears on-screen
- Touch screen used to select letter seen
- Program varies contrast up/down and measures lowest red, green & blue contrast seen
Aircraft Symbols Test

- 5 symbols for each of 7 colors
- Symbol disappears when touched
- The goal is to eliminate all 5 of 1 color as fast as possible
- Response time & errors recorded
Next trial starts with random display (all 35 symbols; eliminate green)
Seven colors equal in brightness (luminance)
Symbols in red, green and blue cone contrast
Color Book Tests (PIPs)

All carriers passed Ishihara & Dvorine

2 of 10 missed 1 red-green HRR plate but made no errors on diagnostic plates
D15 & FM 100 Hue Results

- Color Ordering Tests
- All carriers passed normal and de-saturated D15
- 8/9: normal on FM 100 Hue (<100 errors)
  - (5): <13 errors, (2): 52 & 66 errors
  - (1): 88 errors
  - (1): 120 errors
Carriers had slightly longer response times for grey and green but most response times were within normal limits.
Aircraft Symbols Test Results

- At low contrast error rate was significantly higher for carriers (2-tailed t-test, p < 0.05):
  - Mean for normals: 1.8 errors
  - Mean for carriers: 3.4 errors
  - 6 of 8 carriers made > 2 errors (one subject not tested)
  - Only 5/16 normals made > 2 errors
CCT Results

- 6 of 9 carriers were > 2SD below normal on the CCT.
- Decreases on the CCT were less than those shown by hereditary color vision deficient individuals.
Cone Contrast Test Results

Faith, Service, Innovation, Truth, Education

Right Eye

Color deficiency

Protan
Deutan
Normal Red
Normal Green

Carriers
Normal

Left Eye

0  20  40  60  80  100
Conclusions

- Carriers of color deficiency perform within normal limits on most color tests, but some show sub-clinical deficiency at low color contrast.
Conclusions

- Unlikely that these sub-clinical deficiencies limit performance.
- However, additional stressors…
  - Low-light
  - Altitude/hypoxia
  - Fatigue &/or stress
- Could possibly combine with these effects to decrease performance.
Conclusions

➢ It is important to distinguish between color vision deficiency in carriers vs. subtle deficiency which can occur as an early sign of various diseases.