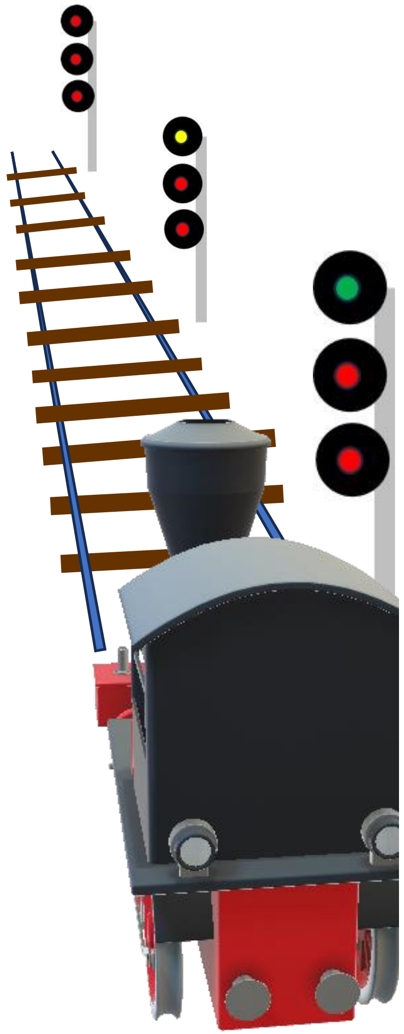
Color Vision Testing for the Railways

Jeffery K Hovis[1]
David Oliphant[1]
Ali Hadi Almustanyir[1,2]
[1] School of Optometry and Vision Science
University of Waterloo, Waterloo, ON
[2] Department of Optometry Science
King Saud University
Kingdom of Saudi Arabia

UNIVERSITY OF WATERLOO | SCHOOL OF OPTOMETRY & VISION SCIENCE

Train Movement

- Train movement on railways is often governed by wayside signal lights using the blocking system
  - Signal sets speed within the block
- Want to be sure the engineer and conductor can identify the signals correctly



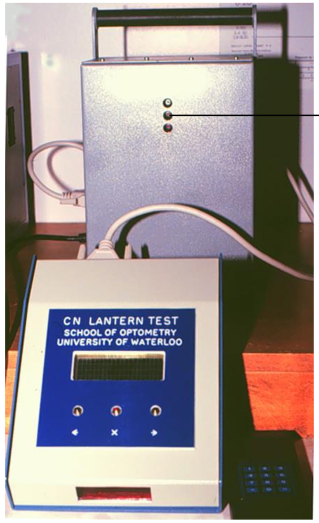
Introduction

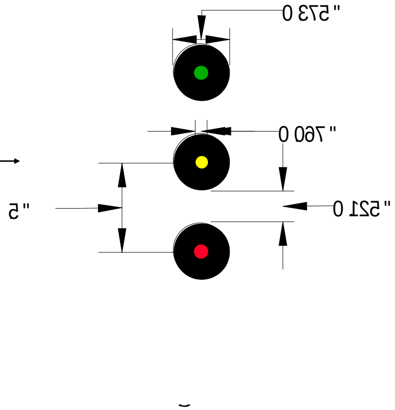
- The issue of the appropriate color vision test for the railroad job-demands is not a new problem.
- Thomson and Thomson (1903) wrote,
  - "Whilst the *(Holmgren)* wool test have been accepted universally as requisite for the detection of color defects, the employees of railroads and their friends have always objected to their use as having no relation to their daily duties; and have demanded such colors as are employed as signals."
- Because of this and other concerns, several US rail companies added a lantern test designed to simulate rail signal lights to their testing protocol by the early 1900s.
- Unsure why lantern tests fell out of favor for the US railways.
- In Canada, a lantern test continued to be used in lieu of, or in conjunction with, a field test.
  - The Holmes-Wright A (HWA) lantern was one of the more common ones (Holmes & Wright, 1982).
  - The HWA presents lights similar to aviation and marine signal light colors - no face validity railway signals
- Japanese railways have lantern tests; but the green and yellow test lights are outside the American Association of Railways (AAR) limits (Takahashi, et al., 1995; Tanabe, et al., 1995)
- Railcorp and UNSW in Australia developed lantern test that simulates LED wayside signal lights (Casolin, et al 2011)

Introduction

- The motivation for the CNLan was
  - In addition to the face validity issue, HWA lantern was becoming more difficult to find
  - CN Railway had several concerns about their practical test
- Their practical test
  - Identify the colors of 10 different triplet wayside signals viewed from 1 mile between 10 AM and 2 PM on a clear or partly cloudy day.
    - Not possible to have a 1 mi viewing distance at some locations
    - Weather
    - Not well controlled- administration biases and other procedural issues

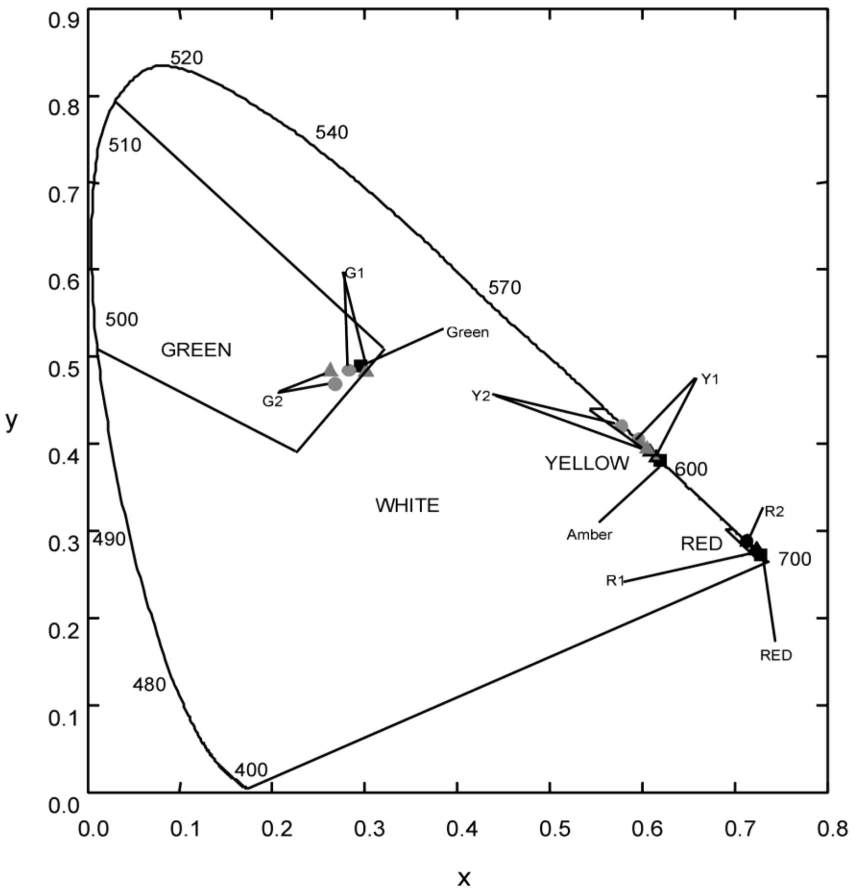
Design





- 4.6 m (15 ft) viewing distance using typical office room lighting
- Gray background reflecting 20% of the incident light - luminance of 30 to 40 cd/m^2
- Angular dimensions of the lights- equivalent to viewing the wayside signals from 0.5 km (0.3 mi).
  - Ensure that the brightness was sufficient so color-normals could identify the lights correctly
- Vertical triplet
  - most complex signal display used on Canadian railways
  - triplet was used in the actual field trial.

Design



Squares are the locations of filters taken from a wayside signal lights, triangles are the CNLan colors and circles are the colors for the simulation display

PRESENTATION NUMBER	LIGHT POSITION	COLOR
1**	TOP	G2
	MIDDLE	Y2
	BOTTOM	R2
2*	TOP	R1
	MIDDLE	Y1
	BOTTOM	G1
3*	TOP	R2
	MIDDLE	R1
	BOTTOM	R2
4	TOP	Y1
	MIDDLE	Y2
	BOTTOM	Y1
5*	TOP	G1
	MIDDLE	R2
	BOTTOM	R1
6*	TOP	Y1
	MIDDLE	G2
	BOTTOM	R2
7*	TOP	Y1
	MIDDLE	Y1
	BOTTOM	R1
8*	TOP	R1
	MIDDLE	Y1
	BOTTOM	R2
9*	TOP	Y2
	MIDDLE	G2
	BOTTOM	R1
10*	TOP	R2
	MIDDLE	Y2
	BOTTOM	G1
11	TOP	G2
	MIDDLE	G2
	BOTTOM	G1
12**	TOP	G2
	MIDDLE	G1
	BOTTOM	R2
13**	TOP	Y2
	MIDDLE	G1
	BOTTOM	R1
14	TOP	G2
	MIDDLE	G1
	BOTTOM	Y2
15	TOP	G2
	MIDDLE	Y1
	BOTTOM	Y2

- Single asterisks -an actual signal sequence
- Double asterisks the reverse order of an actual signal sequence
- Approximately the same frequency of each color
- Point brilliance
  - At least 3x above threshold, but varied within and across triplets.
    - Observation that the brightness relationship between the signal lights is not always consistent along the track
  - Light intensity was equivalent to viewing signals from 0.20 km (0.12 mi) to 0.65 km (0.40 mi): mean distance of 0.30 km (0.19 mi)

UNIVERSITY OF WATERLOO | SCHOOL OF OPTOMETRY & VISION SCIENCE

Validation Study

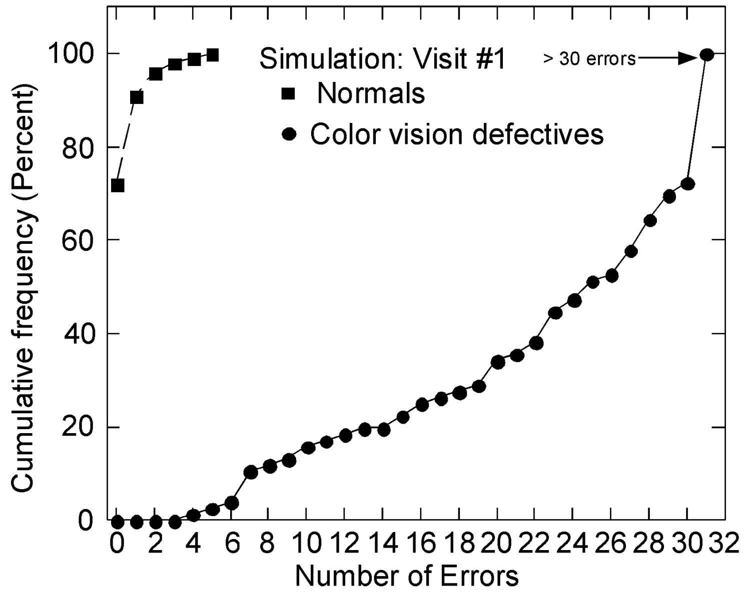
- Simulated field trial
  - *Basic Set-up:* 3-light wayside signal during the day
    - Light size, annulus and separation were equivalent to viewing actual signal lights at 0.8 km (0.5 mi) –ensure that that the point brilliance was sufficiently bright so that color-normals could identify the colors correctly.
  - *Background:* Daylight viewing conditions
    - Wayside signal luminance contrast is near a minimum during the day (except for foul weather conditions)
    - Size was 6 degrees, The luminance surrounding the triplets was 2900 cd/m^2
      - Average luminance within the 6 degree field was 2500 cd/m^2 and 75 cd/m^2 outside of the field
    - The correlated color temperature was 4900°K ~ direct sunlight

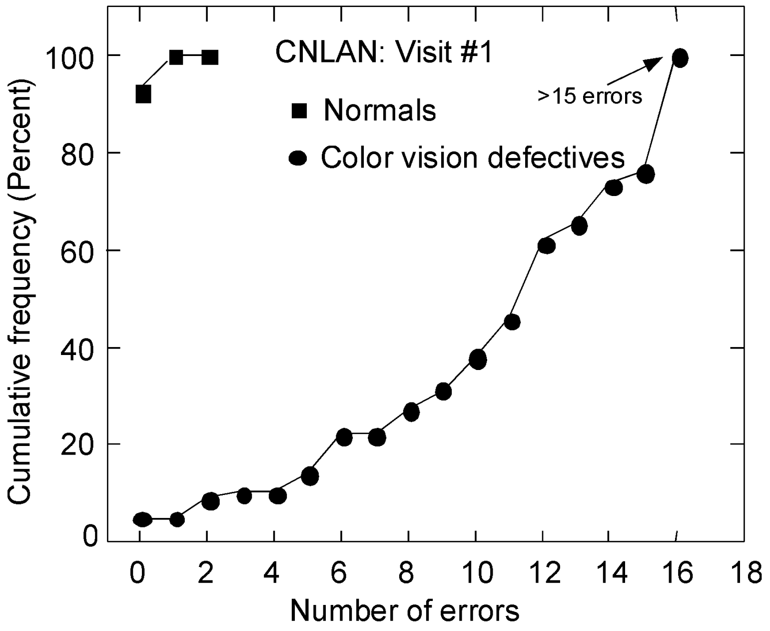
Validation Study

- *Test Light Color and Intensity.*
  - The colored triplets displayed were the actual triplet color codes (RAC, 1990)
  - 11 different triplets were presented twice within a session for a total of 22 presentations.
    - Red was presented twice as frequently as either yellow or green and yellow and green lights were presented at an equal frequency.
  - Point brilliance of lights was established based on the empirical equations derived by Masaki and Tanaka using 2900 cd/m^2 as the background luminance and increased to ensure that color-normal could identify the lights correctly
    - The intensity for certain lights was further increased to introduce brightness differences as a confounding variable so that brightness clues could not be used as secondary information to identify colors.
- The brightness contrast was slightly lower than CNLan
  - Equivalent to viewing the signals from 0.35 km (0.22 mi) to 0.8 km (0.5 mi): mean of 0.43 km (0.27mi)

The Data

- Identification of lights was challenging for the CVD group





The Data

- Looking at only the CVD subjects
  - Passing based on worst normal
  - >5 errors on the Simulation and >1 error on CN Lantern (providing no errors where red was confused with green or vice versa)

Simulation

Lantern	Simulation Pass	Simulation Fail
Pass	**1**	**2**
Fail	**1**	**70**

P_{agree}= 0.40

95% CI: 0.08 to 0.83

Predictive Pass=0.33

95% CI: 0.06 to 0.79

F_{agree} = 0.98

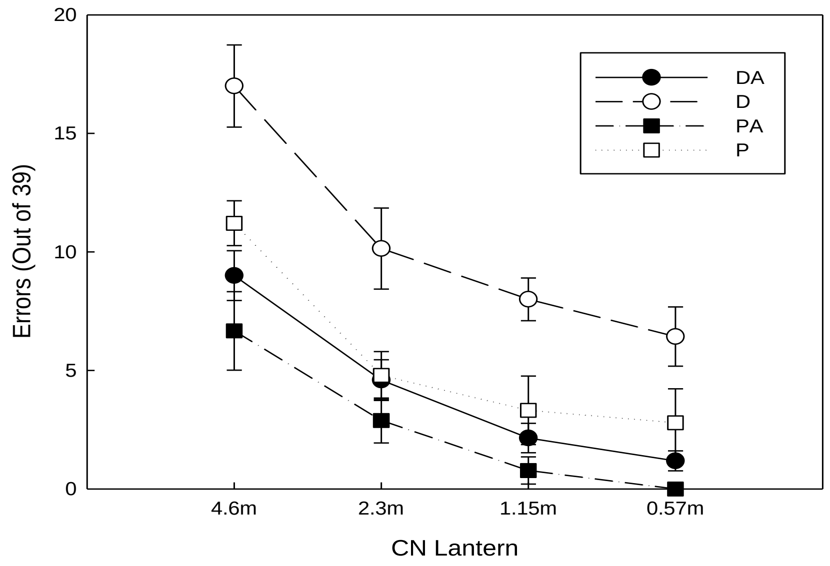
95% CI: 0.92 to 1.0

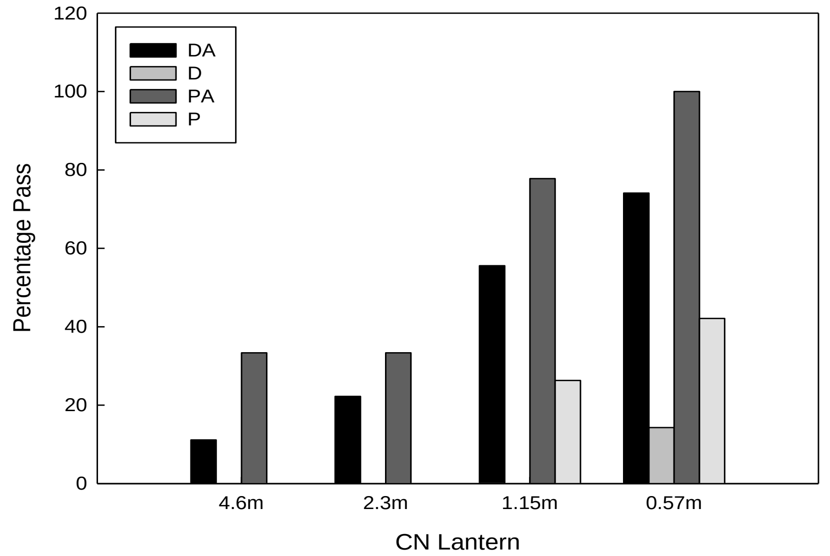
Predictive Fail=0.99

95% CI: 0.93 to 0.1.0

Test Distance

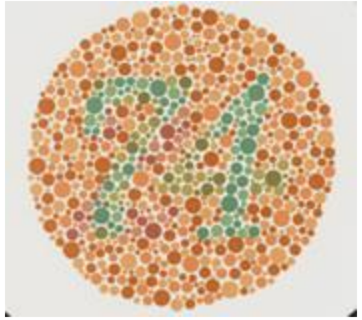
- Well established that CVD performance is better if lights are brighter and larger in size
  - Reducing the viewing distance by a factor of 2 increases the brightness by a factor of 4



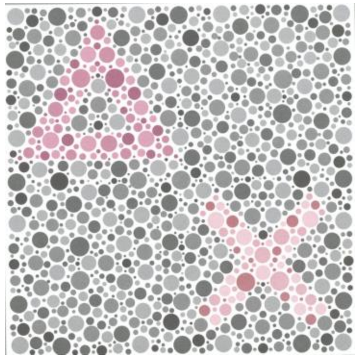


Correlations with other tests

- 38 plate Ishihara

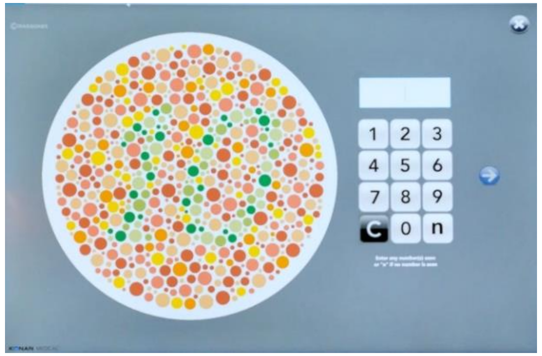


- HRR 4th edition

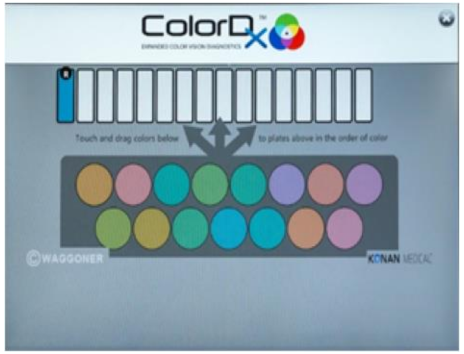


- Farnsworth D15

- ColorDx Extended Adult Series

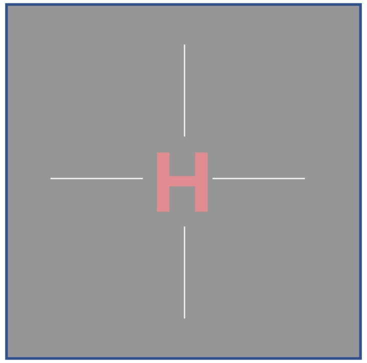


- ColorDx D15

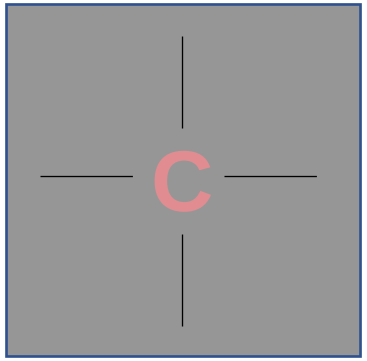


Correlations with Other Tests

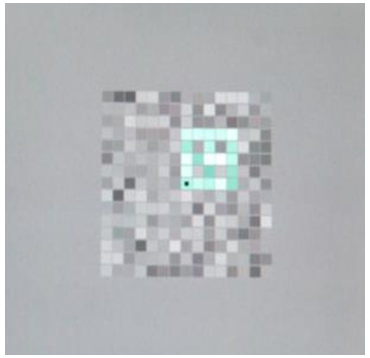
- Rabin Cone Contrast Test (CCT)



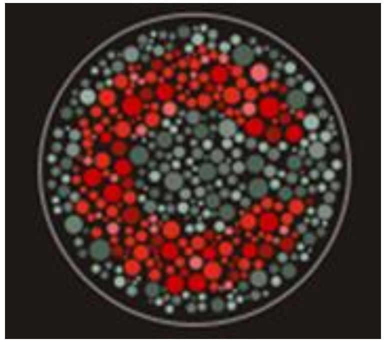
- USAF Automated Vision Test Landolt C (Konan CCT HD)



- CAD

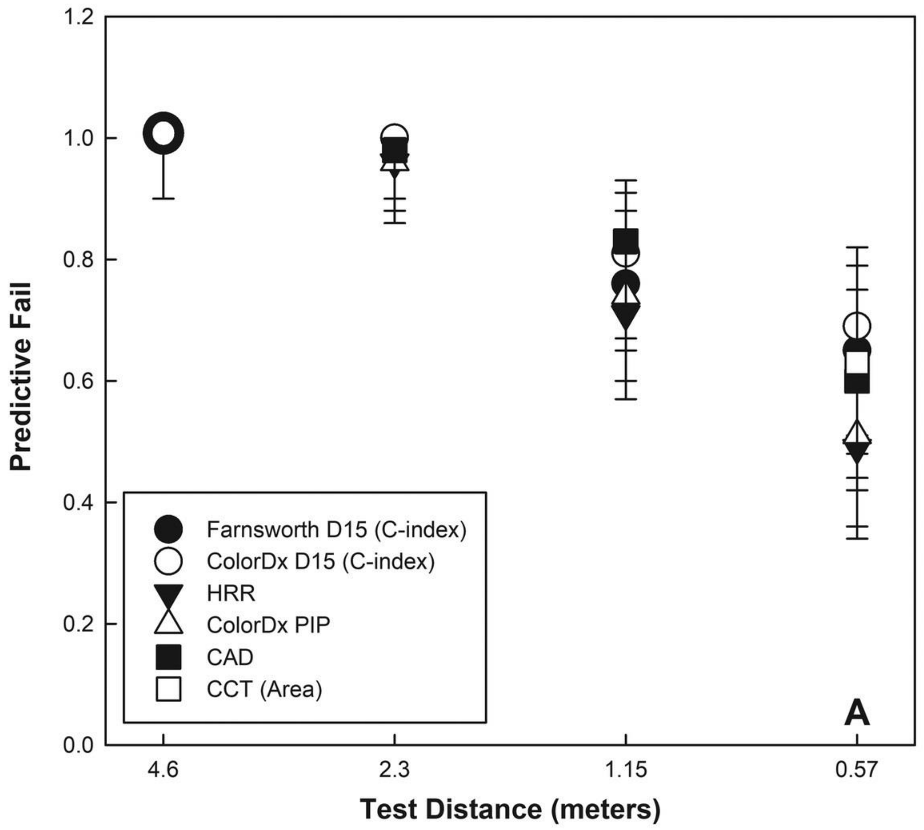


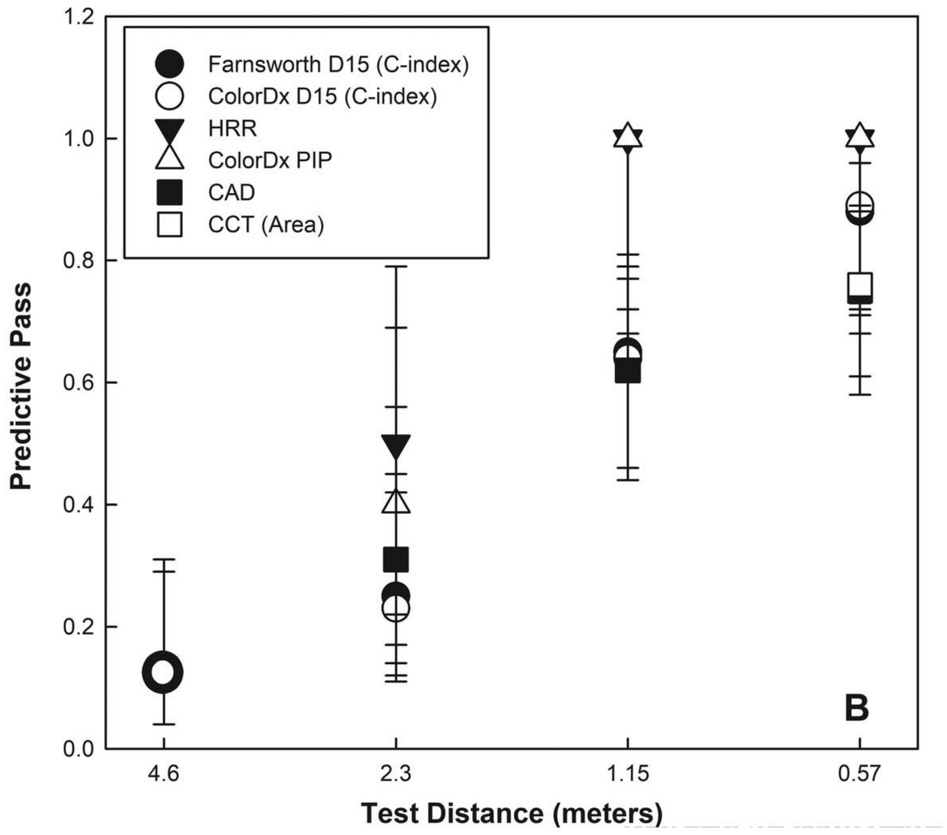
- Cambridge Trivector (CTV)



Predictive Values of the tests for the CNLan

- If you don't see the test, overall agreement was never better than chance at any distances





4.6 m: criteria for HRR and ColorDxPIP is normal color vision. Other distances: failure is moderate or severe diagnosis

Conclusions

- Identifying wayside signal lights can be challenging for a person with a color vision deficiency
  - Trains traveling ~100 mph
  - Triplet wayside light configuration
  - Brighter backgrounds
- CNLan provides a validated test for determining which CVD individuals can perform the task
- If clinical tests are used,
  - essentially normal color vision is required for most challenging conditions
  - Individuals with a mild defect (HRR or ColorDx, D15) are likely to perform safely in situations with shorter sighting distances and less complex signal configurations.

Acknowledgements

- Funding provided by
  - CN and CPKC railways
  - King Saud University and the Saudi Arabia Cultural Bureau in Ottawa

Thanks to my collaborators

- Daniel Fusco
- Zach Barnes
- John Peacock
- Shankaran Ramaswamy
- Vince Law
- Robin Jones
- Andrew Nowinski