
Colour Vision Assessment Course - Leipzig University
26th October 2012
COLOUR VISION ASSESSMENT IN OCCUPATIONAL ENVIRONMENTS
1
2
3
4
Applied Vision Research Centre
JOHN BARBUR
Applied Vision Research Centre,
The Henry Wellcome
Laboratories for Vision Science,
School of Health Sciences,
City University London
City University
Age-corrected, Normal Limits
6
3
0
0
30
60
90


SETTING MINIMUM COLOUR VISION REQUIREMENTS WITHIN VISUALLY-DEMANDING OCCUPATIONAL ENVIRONMENTS
TRADITIONAL JUSTIFICATION FOR THE INTRODUCTION OF COLOUR SCREENING TESTS
▪ To ensure that all applicants that pass can carry out the most visually-demanding, colour-related tasks with the same accuracy as normal trichromats
DEFAULT SOLUTION: Screen for normal trichromacy (i.e., pass only normal trichromats)
Traditional Colour Assessment Tests
1
2
3
4
5

SETTING MINIMUM COLOUR VISION REQUIREMENTS
(MORE RECENT OBJECTIVES)

A NEW, ACCEPTABLE JUSTIFICATION FOR SETTING MINIMUM COLOUR VISION REQUIREMENTS

- **To ensure that all applicants that can carry out the most demanding, colour-related tasks as well as normal trichromats <u>pass</u> and are therefore not discriminated against <u>on the basis of their colour deficiency</u>**

What is the outcome of current practices?

- **Current screening tests and procedures do not guarantee that one achieves either the traditional or the new objective**
- **On many tests / protocols colour deficient subjects pass as normal trichromats or normal trichromats can fail**
- **The acceptance of arbitrary pass / fail error scores in some tests does not guarantee that those that pass are safe**

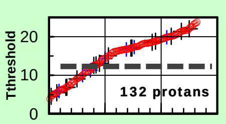
HOW DO WE CHANGE CURRENT PRACTICES TO AVOID THESE UNWANTED OUTCOMES?

<u>PROJECT REQUIREMENTS</u>:

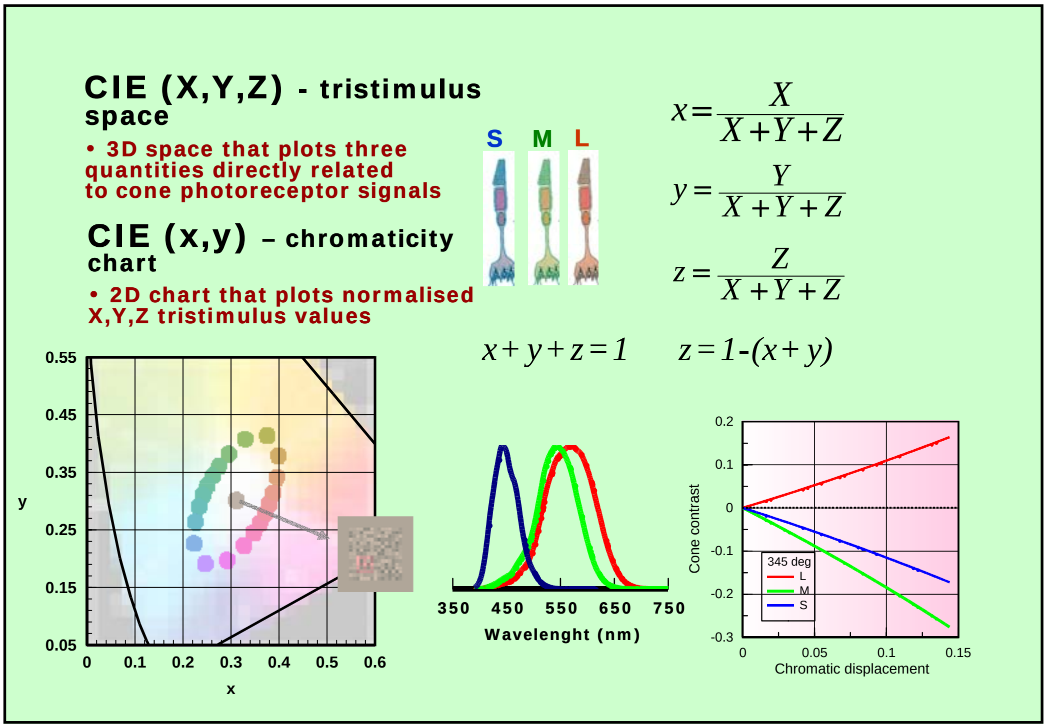
- **We need a sensitive and efficient test that isolates red/green and yellow/blue colour signals, quantifies the severity of colour vision loss and identifies the type of deficiency involved**

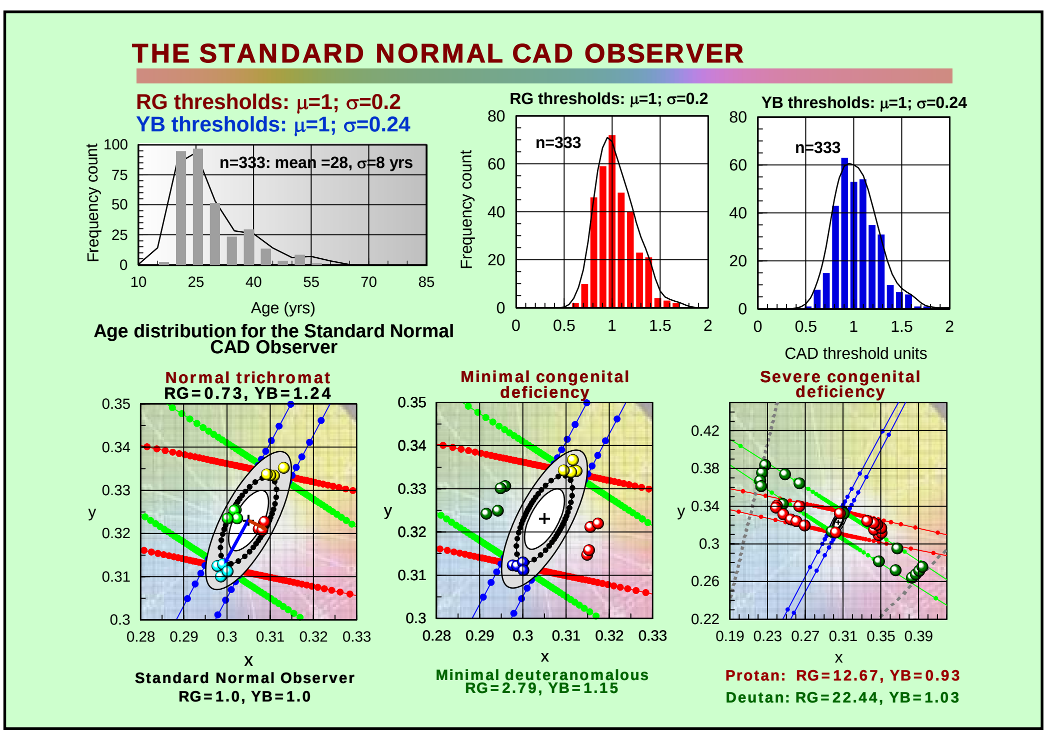
- **We need to carry out detailed visual task analysis within a specified working environment (such as commercial aviation) to identify the most demanding, safety-critical, colour-related tasks**

- **Produce accurate laboratory simulation of the most safety-critical, colour-related visual tasks**



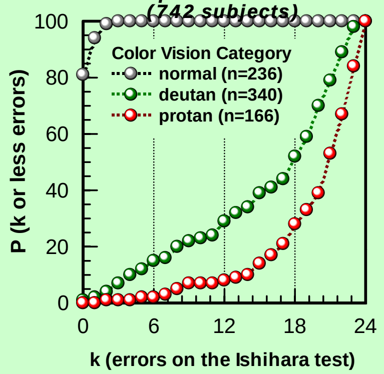
- **Establish limits of colour vision loss within which subjects with mild congenital deficiency can carry out the safety-critical, colour-related tasks with the same accuracy as normal trichromats**


CIE (X,Y,Z) - tristimulus space
• 3D space that plots three quantities directly related to cone photoreceptor signals
CIE (x,y) – chromaticity chart
• 2D chart that plots normalised X,Y,Z tristimulus values
S M L
$x = \frac{X}{X+Y+Z}$
$y = \frac{Y}{X+Y+Z}$
$z = \frac{Z}{X+Y+Z}$
$x + y + z = 1$ $z = 1 - (x + y)$
0.55 0.45 0.35 0.25 0.15 0.05
y
0 0.1 0.2 0.3 0.4 0.5 0.6
x
350 450 550 650 750
Wavelenght (nm)
0.2 0.1 0 -0.1 -0.2 -0.3
Cone contrast
345 deg
L
M
S
0 0.05 0.1 0.15
Chromatic displacement


THE STANDARD NORMAL CAD OBSERVER
RG thresholds: μ=1; σ=0.2
YB thresholds: μ=1; σ=0.24
100 75 50 25 0
Frequency count
n=333: mean =28, σ=8 yrs
10 25 40 55 70 85
Age (yrs)
Age distribution for the Standard Normal CAD Observer
RG thresholds: μ=1; σ=0.2
80 60 40 20 0
Frequency count
n=333
0 0.5 1 1.5 2
YB thresholds: μ=1; σ=0.24
80 60 40 20 0
n=333
0 0.5 1 1.5 2
CAD threshold units
Normal trichromat
RG=0.73, YB=1.24
0.35 0.34 0.33 0.32 0.31 0.3
y
0.28 0.29 0.3 0.31 0.32 0.33
x
Standard Normal Observer
RG=1.0, YB=1.0
Minimal congenital deficiency
0.35 0.34 0.33 0.32 0.31 0.3
y
0.28 0.29 0.3 0.31 0.32 0.33
x
Minimal deuteranomalous
RG=2.79, YB=1.15
Severe congenital deficiency
0.42 0.38 0.34 0.3 0.26 0.22
y
0.19 0.23 0.27 0.31 0.35 0.39
x
Protan: RG=12.67, YB=0.93
Deutan: RG=22.44, YB=1.03

THE ISHIHARA TEST – SCREENING FOR NORMAL TRICHROMACY?

Cumulative percentage of errors made by normal trichromats and subjects with deutan and protan like deficiencies on the first 25 plates of the IH test (742 subjects)



100% of all normal trichromats pass with 4 or less errors. 80.9% (191) normals make no errors on the first 25 plates of the 38-plate version

10% of deutans (34 subjects) also pass with 4 or less errors

1% of protans pass with 4 or less errors

HW lantern

To separate normal trichromats from the other colour deficient subjects who fail at least one Ishihara plate, in the past the CAA employed the HW lantern as a secondary test.

100% of all normal trichromats pass the HW type A lantern

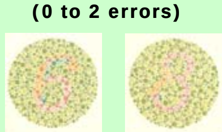
10% of deutans also pass the HW lantern test

All protans fail the HW lantern test

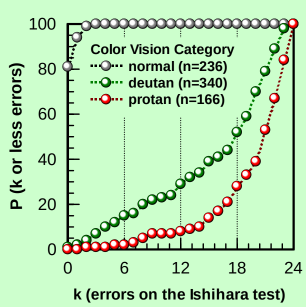
Conclusion: 10% of subjects with minimal colour vision loss cannot be distinguished from normal trichromats and are classed as "normal"

THE ISHIHARA COLOUR TEST – How can a congenitally colour deficient applicant learn to pass the test?

Ishihara test diagnosis
(0 to 2 errors)

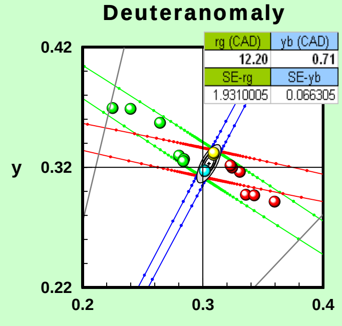


Diagnosis: Normal trichrom



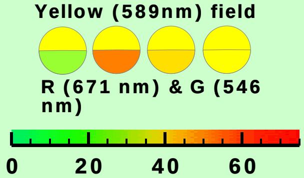
CAD test diagnosis

Severe Deuteranomaly



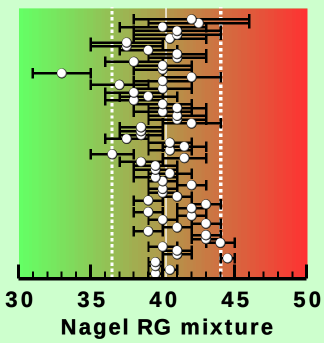
THE NAGEL ANOMALOSCOPE - SCREENING FOR NORMAL TRICHROMACY?

Variation in Nagel test parameters in normal trichromats and in subjects with deutan and protan like deficiencies **(Vis. Neurosci. 25(3), 507-516. 2008)**



PARAMETERS EXTRACTED FROM THE MATCH

- **Observer's mean RG setting**
- **Observer's RG range**
- **Mean Y value for each match**



How can we account for:

- ➢**The very small range of red-green mixtures exhibited by some deutans and protans (often smaller than 4 units)**
- ➢**Anomalous matches made by some "normal" trichromats**
- ➢**"Normal" classification of subjects with abnormal chromatic sensitivity**

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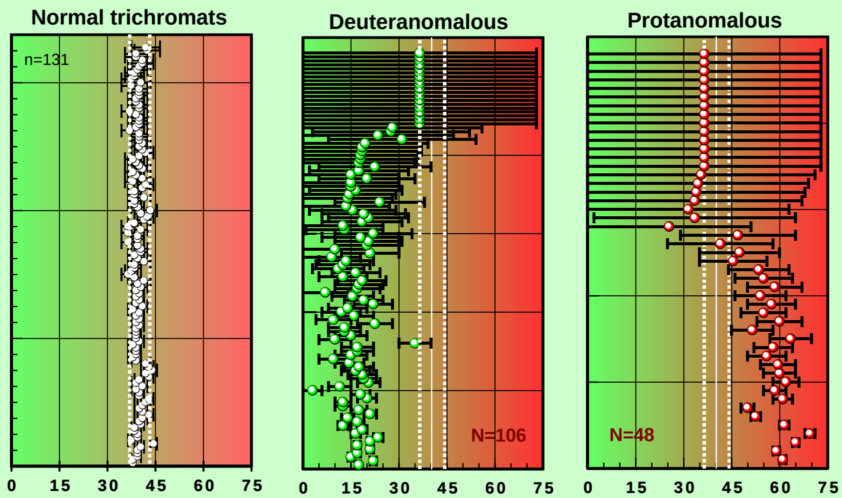

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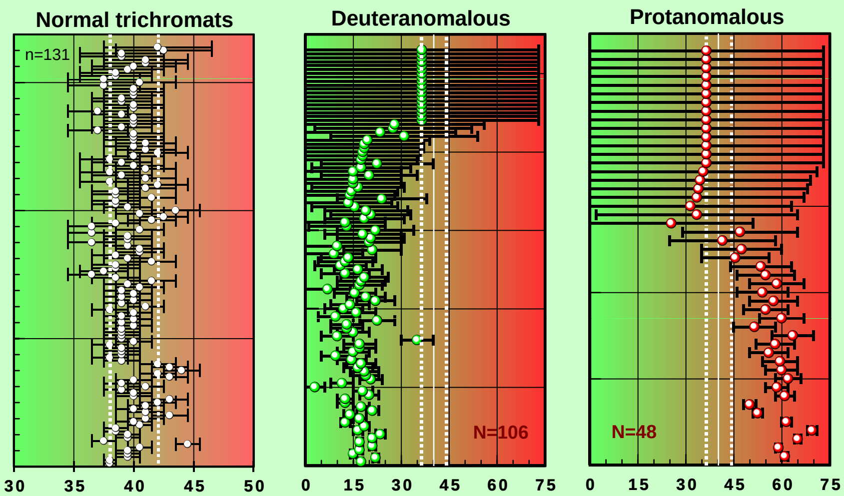
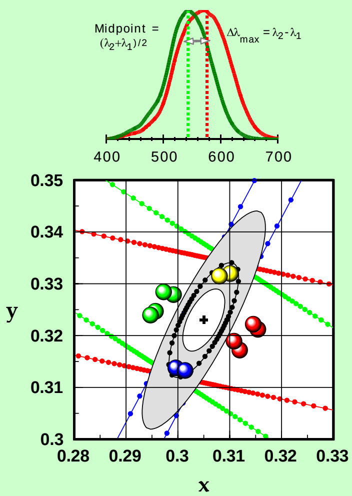
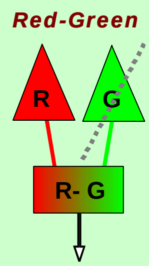


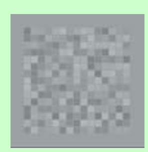
ANOMALOSCOPE MATCH PARAMETERS AND CHROMATIC SENSITIVIY

CAD measures of RG and YB chromatic sensitivity in congenital colour deficiency





Minimal Deuteranomaly

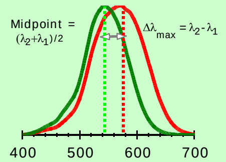


Genetics:	**LLM genes (~ 10 nm)**
Diagnosis:	**Minimal deuteranomalous**
Nagel:	**16-18 (range=3)**
Model:	**67% M>L, $\delta\lambda_{max}$= 10nm**
	OD_M=0.5, OD_L=0. 5
Noise range:	**~ 1**

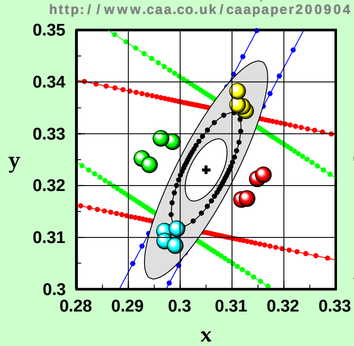
Subject passes IH, AO, D15 and CU

ANOMALOSCOPE MATCH PARAMETERS AND CHROMATIC SENSITIVIY

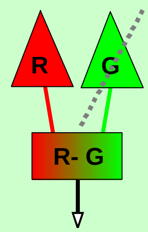
CAD measures of RG and YB chromatic sensitivity in congenital colour deficiency



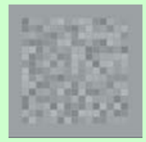
For CAD test see;
http://www.caa.co.uk/caapaper200904



Red-Green



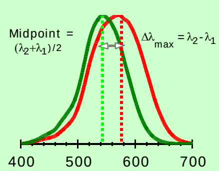
Minimal Deuteranomaly

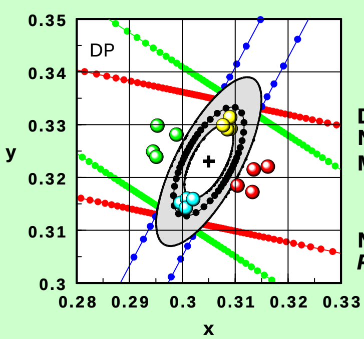


CAD diagnosis: **Minimal deuteranomalous**
Nagel: **40-42 (range=3).**
Model: **30% L>M, 32% M>L, $\delta\lambda_{max}$ ~ 11.5nm, OD_M=0.5, OD_L=0.51**
Noise range: **~ 1.2**
Passes IH (22 out of 25), AO, D15, CU.

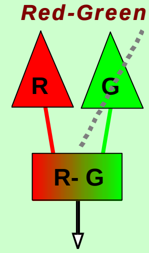
ANOMALOSCOPE MATCH PARAMETERS AND CHROMATIC SENSITIVIY

CAD measures of RG and YB chromatic sensitivity in congenital colour deficiency

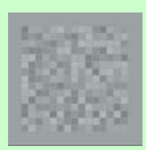




Red-Green

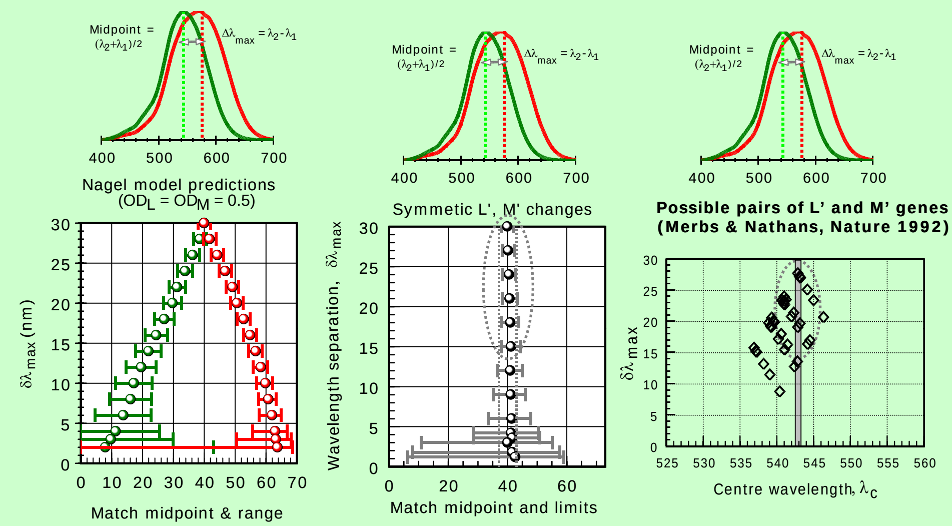


Minimal Deuteranomaly

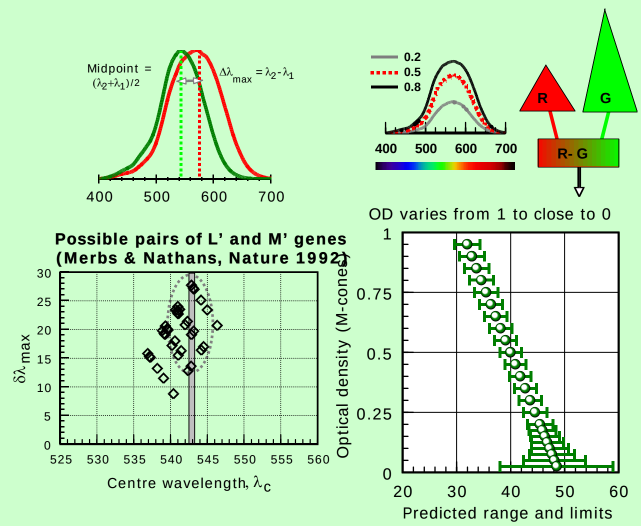


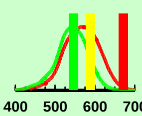
Diagnosis: **Minimal deuteranomalous**
Nagel: **36-38 (range=3)**
Model: **20% L>M, 30% M>L, $\Delta\lambda_{max}$~13.5nm, OD_M=0.5, OD_L=0.5,**
Noise eq. range: **~ 1.2**
Passes IH (15 out of 25 correct), AO, D15, CU

ANOMALOSCOPE MATCH PARAMETERS – *Nagel Model Predictions, effect of $\delta\lambda_{max}$ and optical density changes*



ANOMALOSCOPE MATCH PARAMETERS - *Predicting the effect of optical density changes*



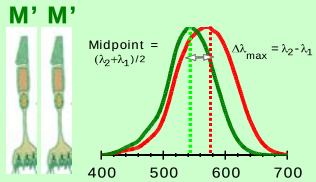


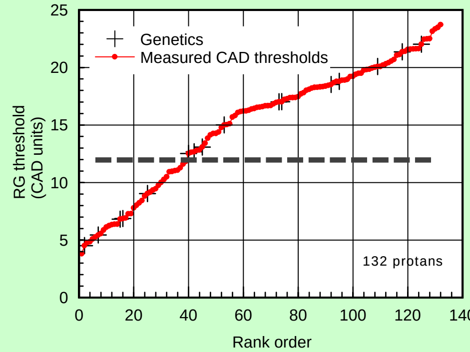
CONCLUSIONS

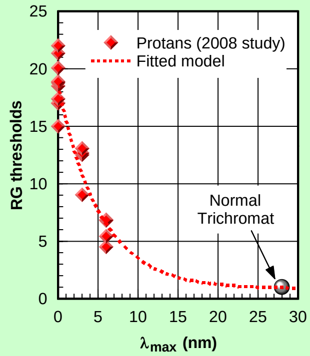
The Rayleigh match can only reflect the equality of L' and M' signals in the yellow and red/green mixture fields and therefore fails to reveal loss of chromatic sensitivity in some subjects with unusual variant genes

Neither the midpoint nor the range correlate well with measures of chromatic sensitivity. The test cannot be used to quantify accurately the severity of colour vision loss or to certify with certainty normal trichromacy

VARIATION IN CHROMATIC SENSITIVITY IN "PROTAN DEFICIENCY"



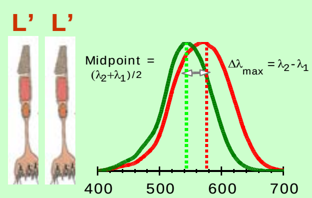


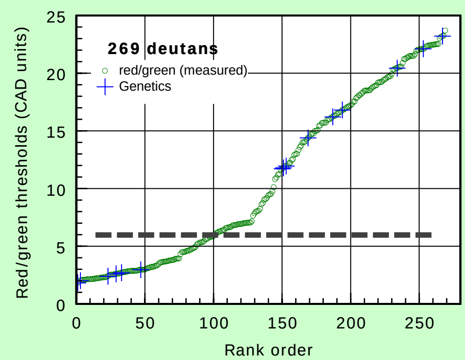


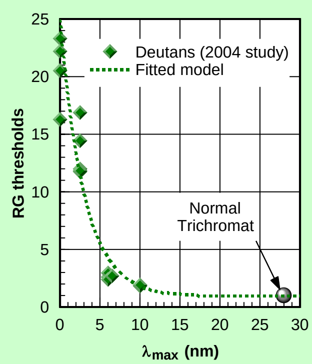
Mean lamba max	Protan deficiency					
M' \ M'	529.7	529.5	529	533.3	531.6	536
529.7	0	0.2	0.7	3.6	1.9	6.3
529.5	0.2	0	0.5	3.8	2.1	6.5
529	0.7	0.5	0	4.3	2.6	7
533.3	3.6	3.8	4.3	0	1.7	2.7
531.6	1.9	2.1	2.6	1.7	0	4.4
536	6.3	6.5	7	2.7	4.4	0

$\delta\lambda_{max}$ changes in protans

VARIATION IN CHROMATIC SENSITIVITY IN "DEUTAN DEFICIENCY"







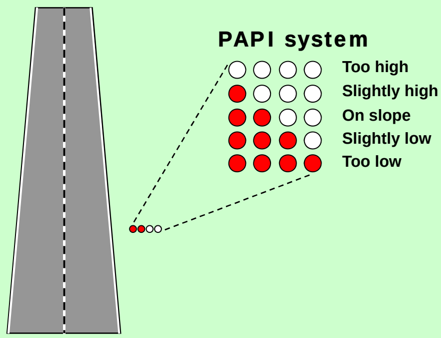
Mean lamba max	Deutan deficiency					
L' \ L'	552.4	556.7	549.6	553	548.8	544.8
552.4	0	4.3	2.8	0.6	3.6	7.6
556.7	4.3	0	7.1	3.7	7.9	11.9
549.6	2.8	7.1	0	3.4	0.8	4.8
553	0.6	3.7	3.4	0	4.2	8.2
548.8	3.6	7.9	0.8	4.2	0	4
544.8	7.6	11.9	4.8	8.2	4	0

$\delta\lambda_{max}$ changes in deutan subjects

VISUAL TASK ANALYSIS FOR AIRLINE PILOTS

- Identification of most demanding, colour-related tasks when no redundancy is involved and correct colour naming is often difficult

PAPI lights



- Other visual signals that make use of color:

Parking lights

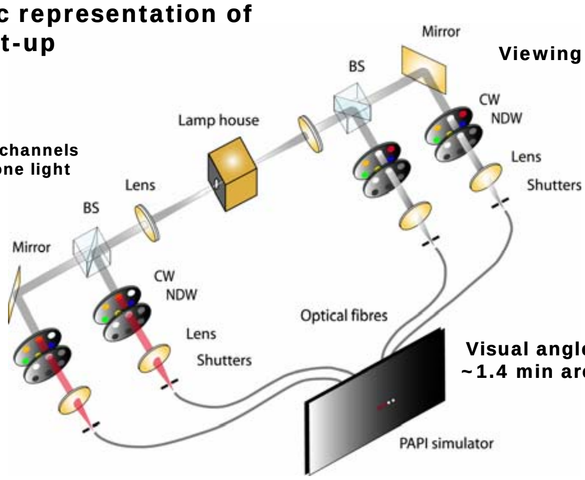
Runway lights

LABORATORY SIMULATION OF PRECISION APPROACH PATH INDICATOR LIGHTS (PAPI)

Schematic representation of optical set-up

Four stimulus channels derived from one light source

Random variation of light intensity

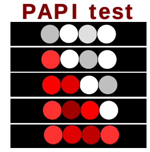


Viewing distance 4.5 m

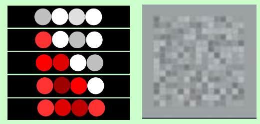
Corresponds to approach distance ~5.54km

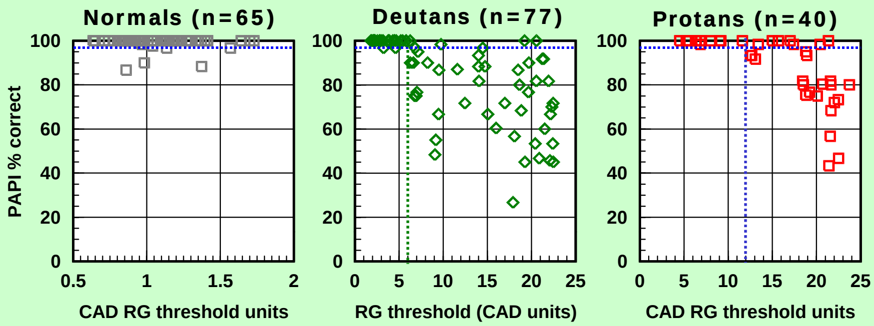
Visual angle ~1.4 min arc

PAPI test

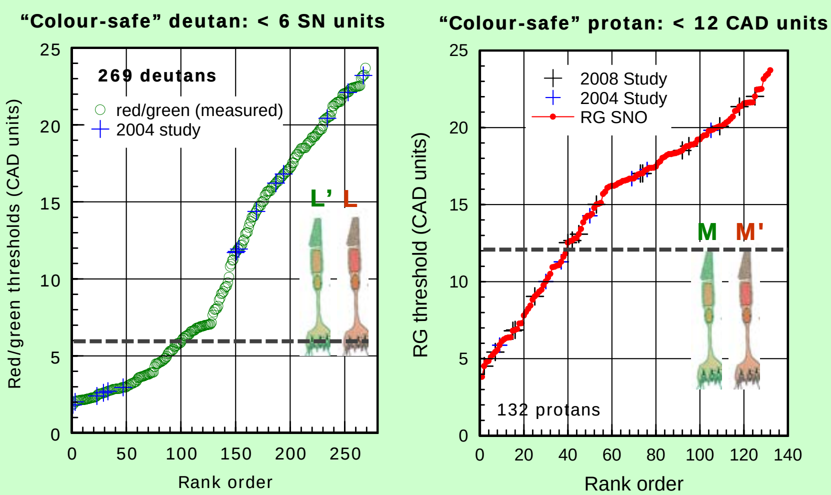


RESULTS: PAPI SCORES v CAD THRESHOLDS



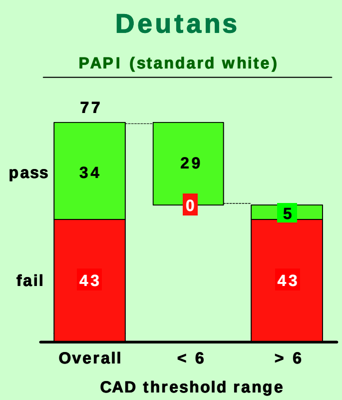


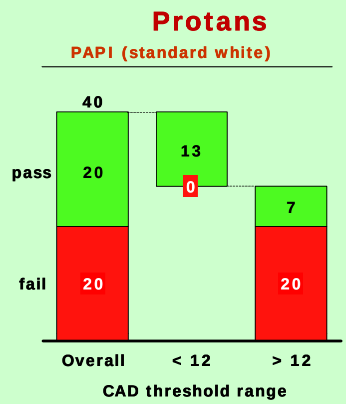
PASS / FAIL LIMITS FOR APPLICANTS WITH DEUTAN- AND PROTAN-LIKE DEFICIENCY



- As a result of imposing the new pass / fail limits for pilots, ~35% of colour deficient applicants are classed as safe to fly

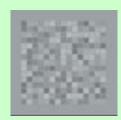
SUMMARY OF RESULTS

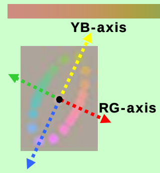




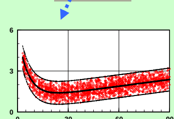
- **The results reveal 37.6% of deutans and 32.5% of protans can be classed as safe to fly**

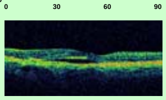
CAD TEST APPLICATIONS WITHIN OCCUPATIONAL AND CLINICAL ENVIRONMENTS



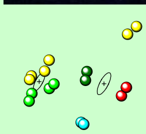


I. **The CAD test quantifies the severity of RG and YB colour vision loss with applications within visually demanding occupational environments. The test cannot be learnt, all cues that can affect the outcome of conventional tests are eliminated**





II. **The age-corrected, normal limits for RG and YB thresholds makes it possible to detect acquired loss of chromatic sensitivity with relevance to the detection of preclinical diseases of the retina and / or systemic diseases that affect vision**



III. **The test can be used to detect automatically any significant changes on repeated testing when monitoring progress of disease or effects of treatment**

IV. **Following the introduction of the new pass / fail certification limits into commercial aviation, 35% of applicants with congenital colour deficiency are now classed as safe to fly**