

Cone-Isolation Contrast Sensitivity

The future of color vision testing

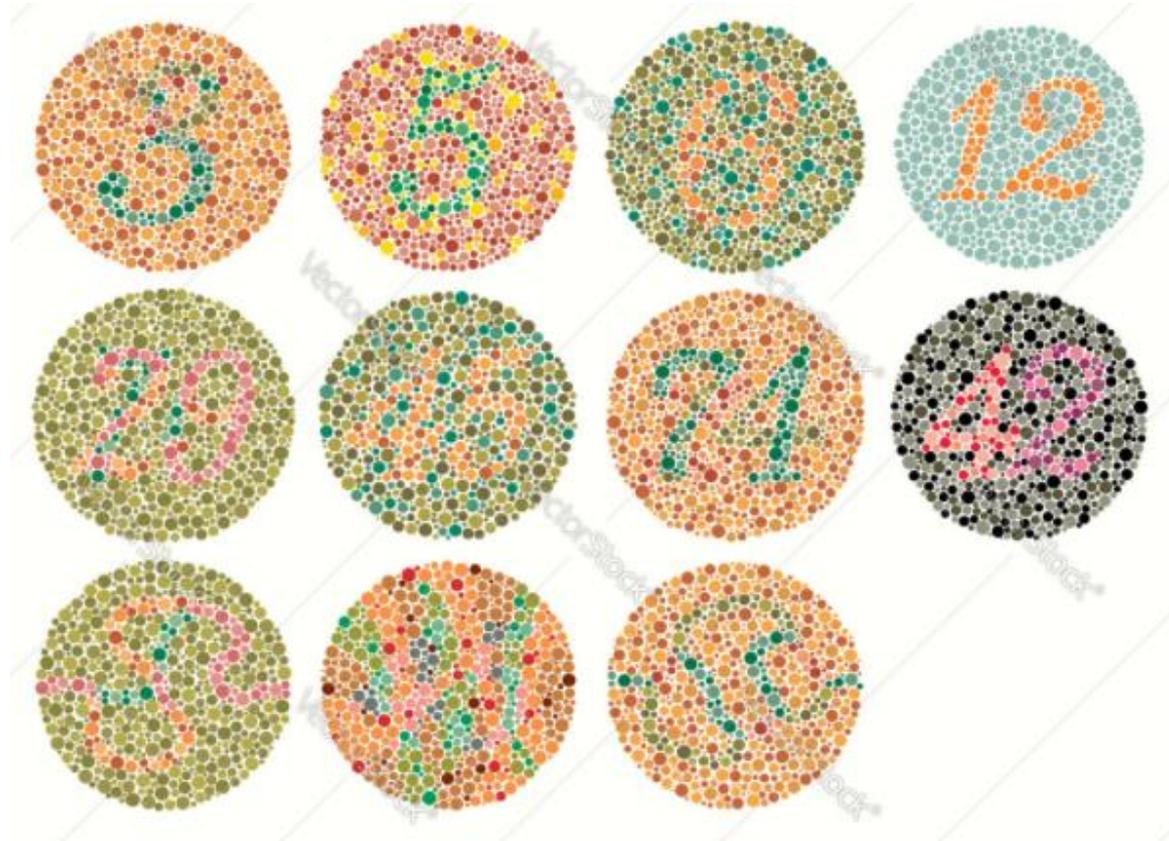
PAUL HARRIS

A solid orange horizontal bar at the bottom of the slide.

Nothing to disclose

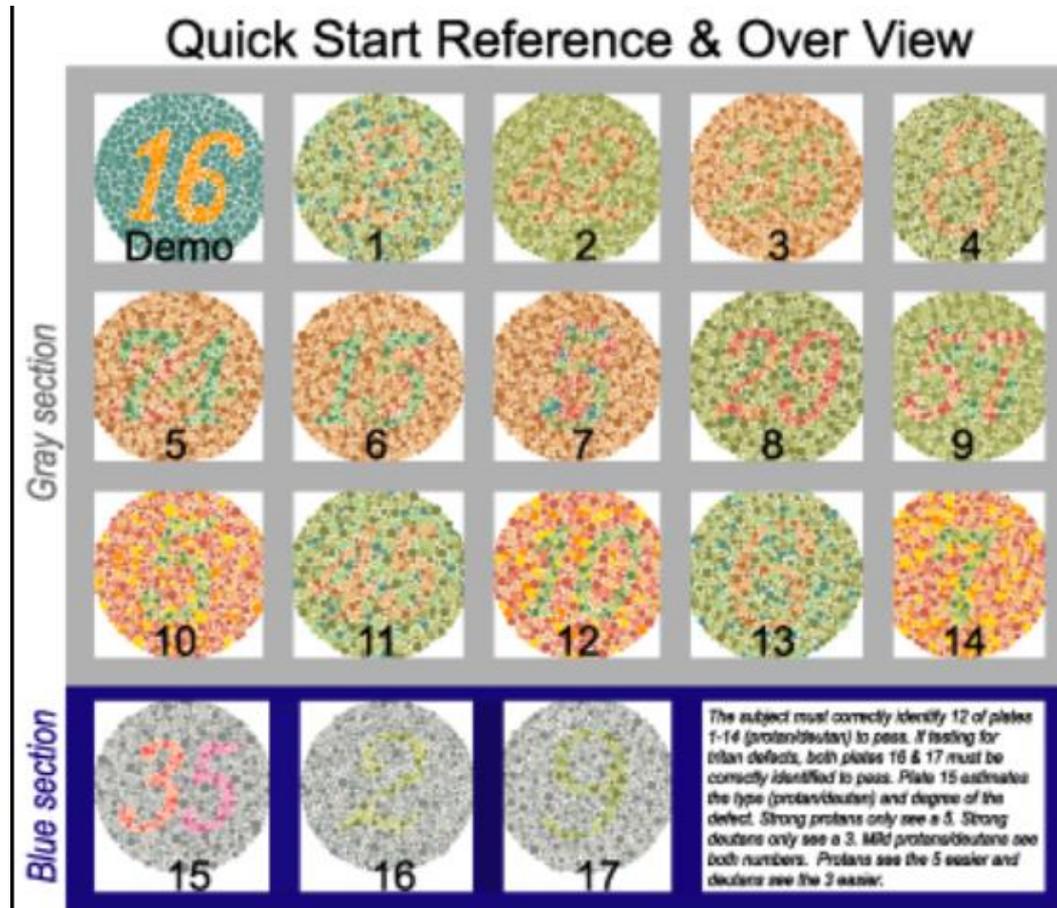
Ishihara

Original Pseudo-Isochromatic "PIP" Plates

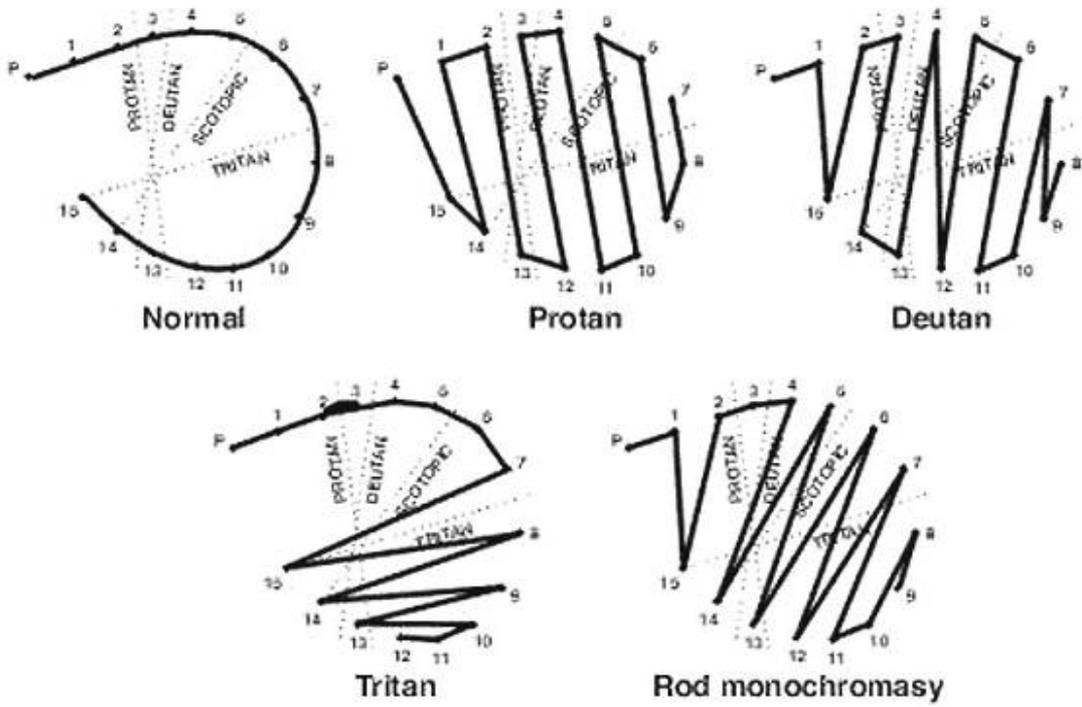


Waggoner PIP-24

Pseudo-Isochromatic in Print and Digitized



D15 Standard and Desaturated Color ordering strategy (abbreviated)



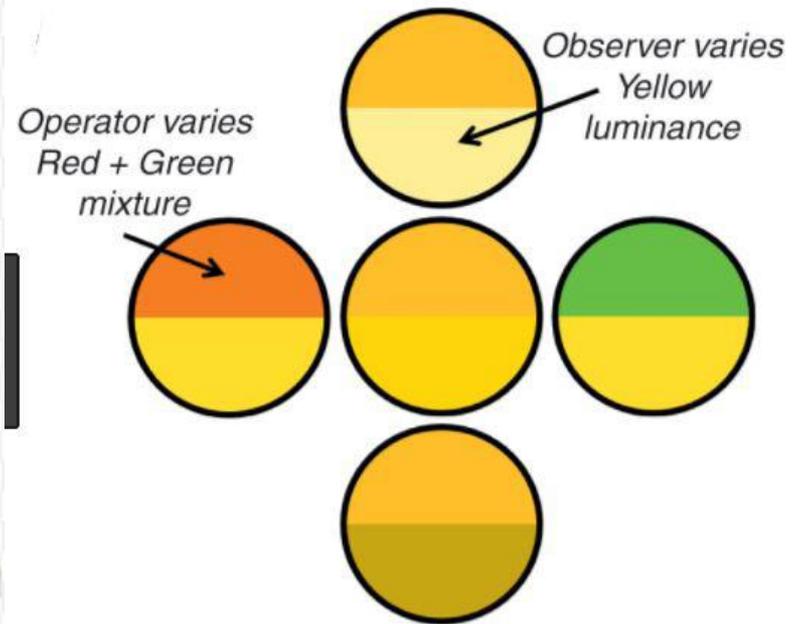
FM-100 (Farnsworth-Munsell)

Color ordering strategy - extended



Oculus Anomaloscope

Rayleigh color mixing



Cone-Isolation (CCT-HD)

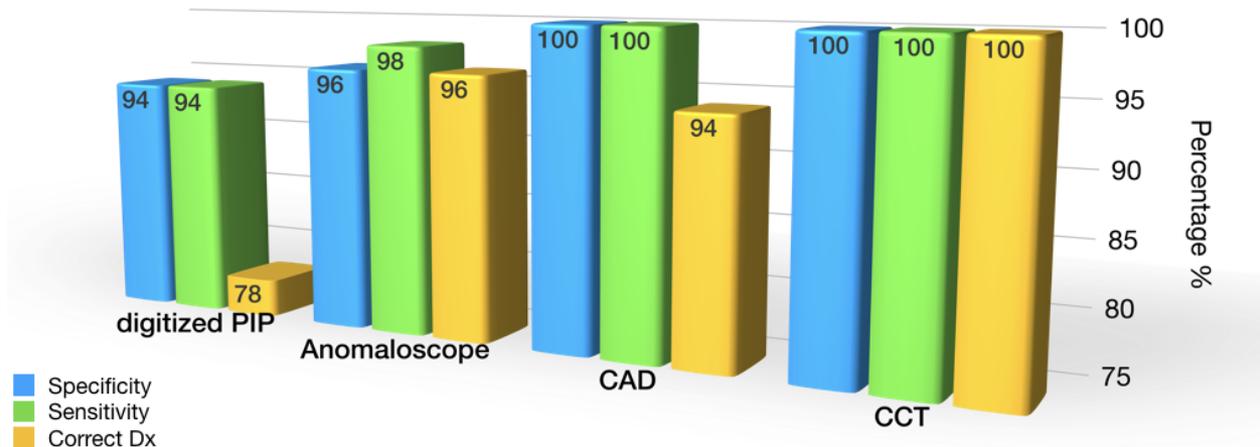
Digital contrast sensitivity tuned to the specific cone populations



USAF Comparative Precision

Color Vision Diagnostic Precision

the foundations for a new gold standard: CCT cone-isolation contrast sensitivity



USAF clinical comparison of four color vision diagnostic devices from 50 color normal and 50 color abnormal subjects: digitized PIP (pseudo-isochromatic), Anomaloscope (Rayleigh color-mixing), CAD (color-camouflage), and CCT (cone-isolation contrast sensitivity).

Illustration adapted from: Gaska, J, Winterbottom M, van Atta A. Operational Based Vision Assessment Cone Contrast Test: Description and Operation. USAF School of Aerospace Medicine, Aeromedical Research Dept. Wright-Patterson AFB; 2016 1.

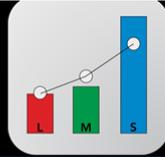
ColorQ

1.0.15



06:29

Paul Harris | 63 M



0.6 m

OD

OS

OU

Test Distance 0.6 m



CCT^{HD}

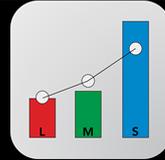
CONE CONTRAST SENSITIVITY

Adaptive



Full Threshold





Instructions

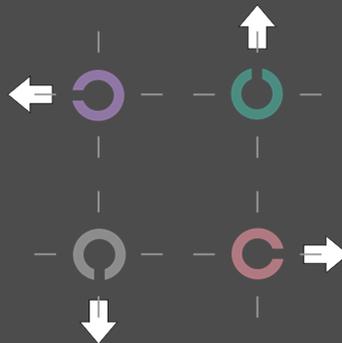
A letter "C" shape is shown briefly in one of four directions and may be one or more colors.

Use the arrows to match the direction of the opening of the "C". A high tone indicates "correct" a low tone indicates "wrong", then the next shape is displayed.

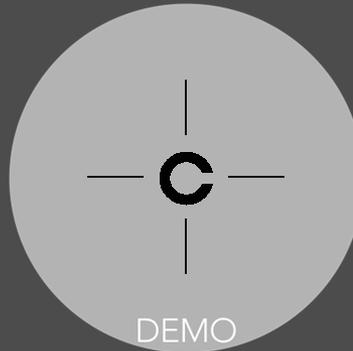
The test calculates the limit of what you can see. When the shape fades to be difficult and then purposely impossible to see, **make your best guess.**

The test ends after several wrong answers and the times to answer are recorded ...try to **answer as quickly as practical.**

Start the test by selecting or with long press of any arrow button

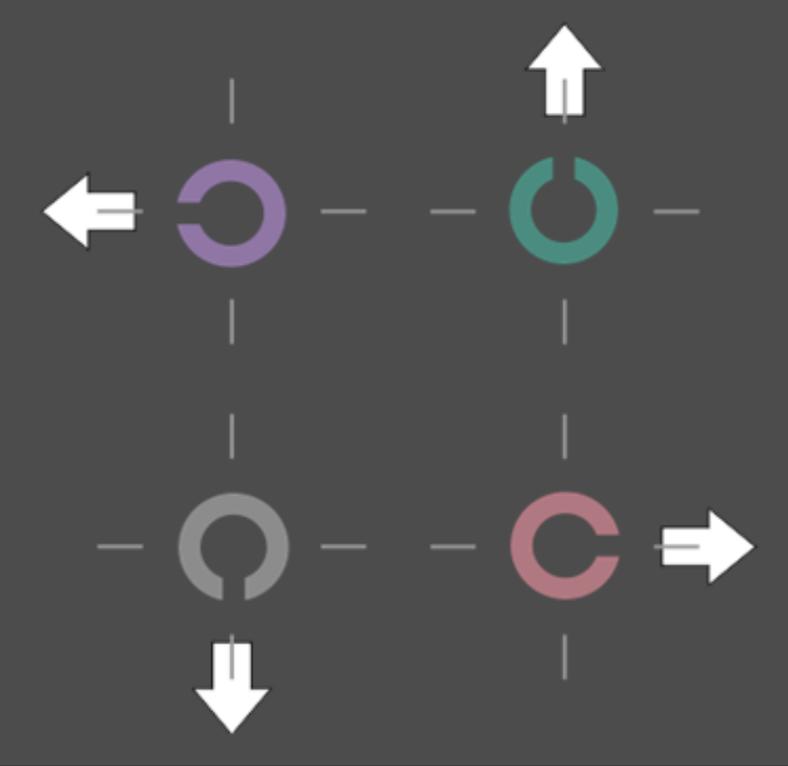


use arrows to match direction of opening of "C"



OD





Video of Cone Isolation Contrast Sensitivity Stimuli



Data from video

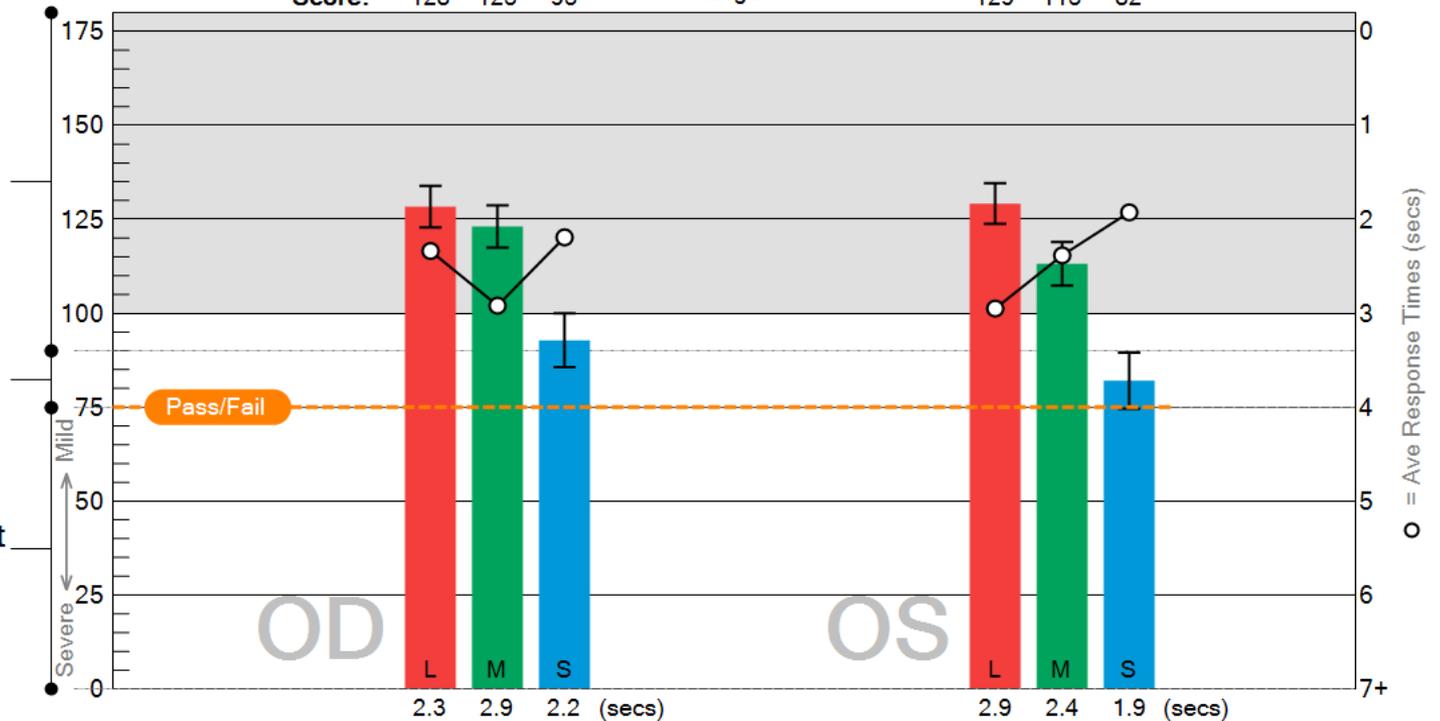
logCS:	2.18	2.13	0.73	Psi Threshold = Standard Error Range	2.19	2.03	0.62
Contrast Threshold(%):	0.7	0.7	18.7		0.6	0.9	24.0
Score:	128	123	93		129	113	82

Normal | Typical
color vision

contrast threshold
range not tested
with CCT (original)

Possible
contrast sensitivity loss
or acquired color deficiency

Color Vision Deficient
genetic or acquired



Some Cases

Train engineer's vision problems led to deadly Oklahoma wreck, NTSB rules

BY CHRIS CASTEEL ccasteel@opubco.com • Published: June 18, 2013 12:00 AM CDT • Updated: June 18, 2013 8:07 PM CDT



WASHINGTON — Two years before his failing vision likely contributed to a fatal crash in the Oklahoma Panhandle, freight train engineer Dan Hall told one of his eye doctors that he was having trouble distinguishing the color of train signals.



Hall and his conductor, Brian Stone, were killed, as was John Hall, the engineer on the other train; the two engineers were not related. Juan Zurita, the conductor on the westbound train, leapt off just before impact.

The National Transportation Safety Board investigated the crash for nearly a year and determined Tuesday that the probable causes were Dan Hall's vision problems and Stone's failure to provide the backup assistance required of a conductor.

Subject: TB

5th generation working for U.P. in family – 18 months from retirement.

DVA uncorrected: OD 20/12 OS 20/12

NVA uncorrected: OD 20/16 OS 20/16

Binocular Balance: +0.50 OU to 20/20

BVA (Manifest): plan OU to 20/12

Peli-Robson CS: OD 3.2% OS 2.5% OU 3.2%

Linear Sine Wave Grating CS:

- 6 cycles per degree OD 0.8% OS 0.8% OU 0.5%
- 12 cycles per degree OD 1.0% OS 0.6% OU 0.6%
- 18 cycles per degree OD 1.6% OS 1.6% OU 1.6%

Subject: TB

Bulls Eye CS

- Mesopic: 18 cpd 12.5% 12 cpd 3.2% 6 cpd 1.8% 3 cpd 0.63% 1.5 cpd 0.63%
- Photopic: 18 cpd 2% 12 cpd 0.63% 6 cpd 0.63% 3 cpd 0.5% 1.5 cpd 0.63%

Stereo

- Randot Stereo: 20 seconds of arc
- Random Dot 3: 12.5 seconds of arc
- Distance Stereo – Chart 2020: 20 seconds of arc

Visual Fields

- 24-2 all normal
- 30-2 all normal
- Goldmann all normal

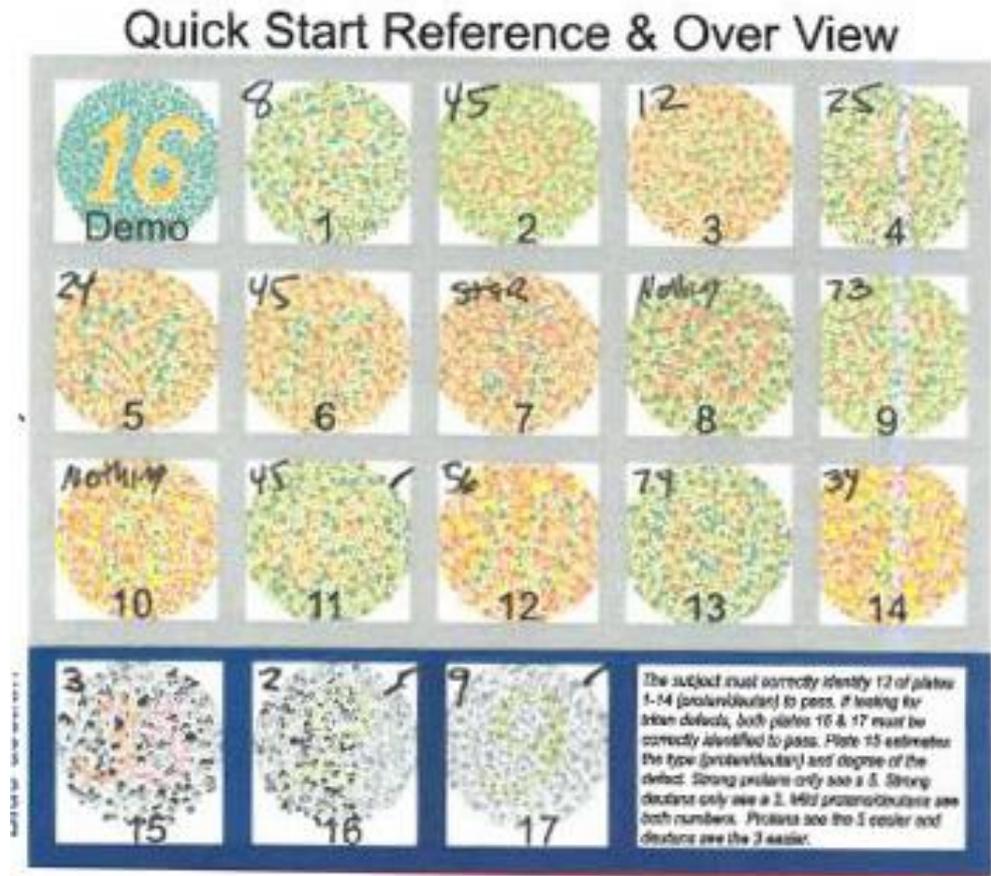
Color Testing

Waggoner PIP-24:
7 of 9 errors

D15 regular and
desaturated OD and OS
separately, all 4 trials
perfectly in order.

D-15 is notoriously
insensitive to low to
moderate deficiencies

Looks right



COLOR I			
Plate sequence	Number on Plate	Subject's Response	
		Pass	Fail
Demonstration Plate			
1	48	✓	
2	67	✓	
3	38		33
4	92		95
5	70		75
6	95	✓	
7	26	✓	
8	2	✓	
9	74		46
10	62		19
11	4		2
12	28		23
13	46	✓	
14	7	✓	
15	39		35

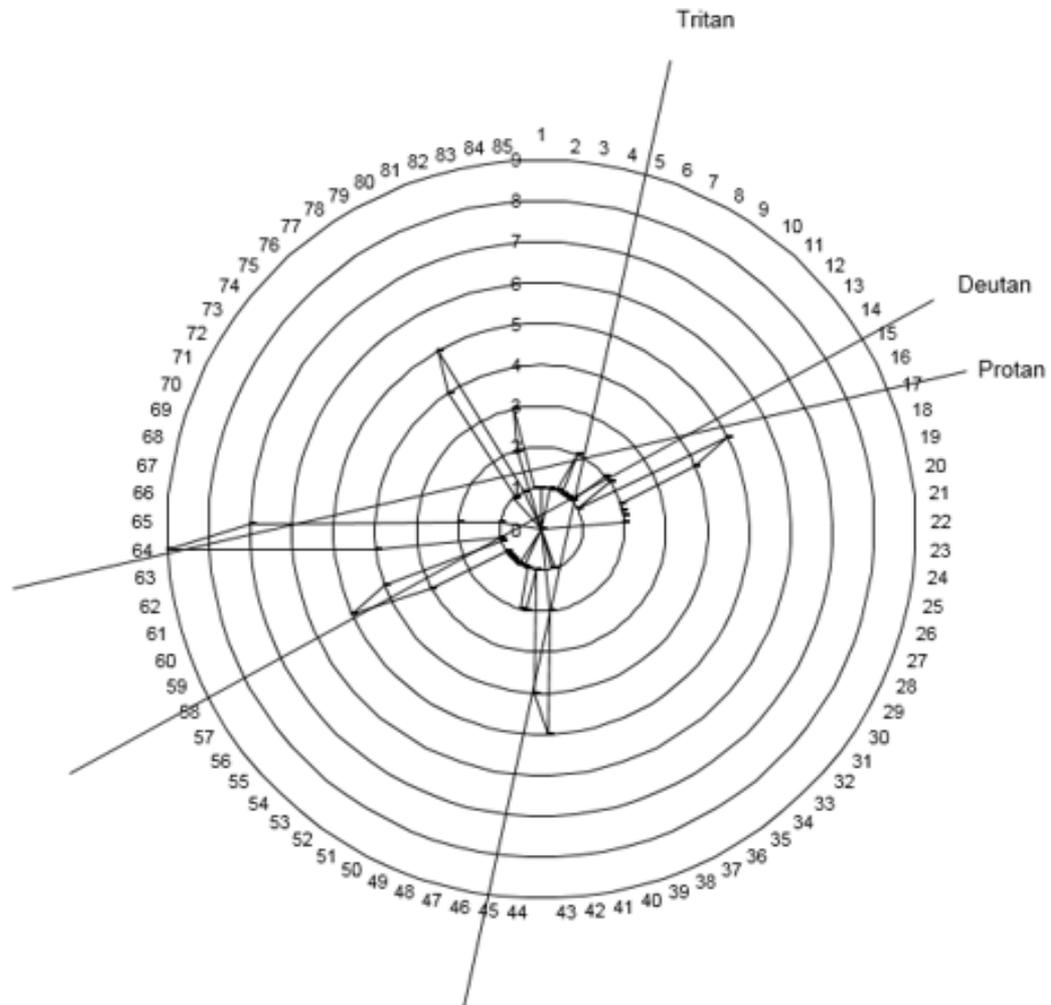
Number of Plate	Normal Person	Person with Red-Green Deficiencies			
1	12	12			
2	8	3			
3	6	5			
4	29	70			
5	57	35			
6	5	2			
7	3	5			
8	15	17			
9	74	21			
10	2	5			
11	6	5			
12	97	x			
13	45	x			
14	5	x			
15	7	x			
16	16	x			
17	73	x			
18	x	5			
19	x	2			
20	x	5			
21	x	73			
		Protan		Deutan	
		Strong	Mild	Strong	Mild
22	26	6	(2)6	2	2(6)
23	42	2	(4)2	4	4(2)
24	55	5	(3)5	3	3(5)
25	96	6	(9)6	9	9(6)

79
65

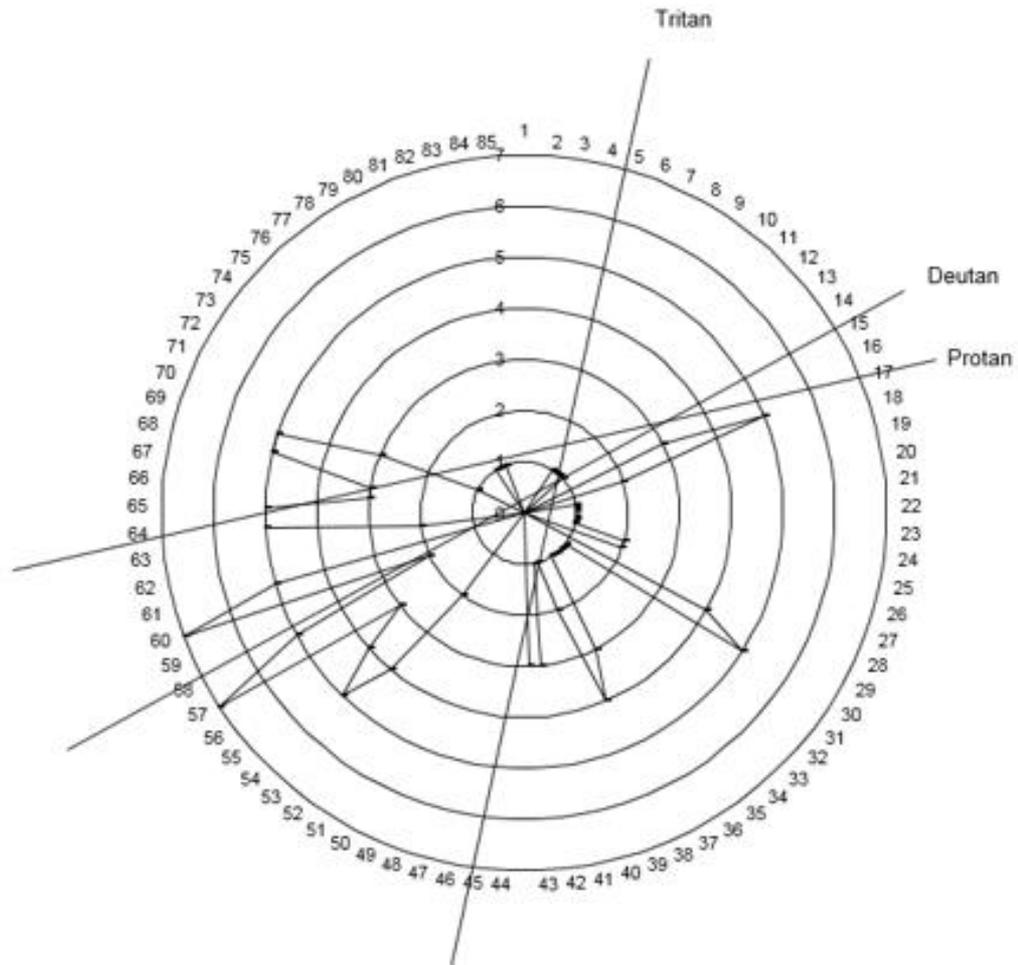
37

8

Farnsworth-Munsell 100 Hue Test



Farnsworth-Munsell 100 Hue Test



Severe Deutan

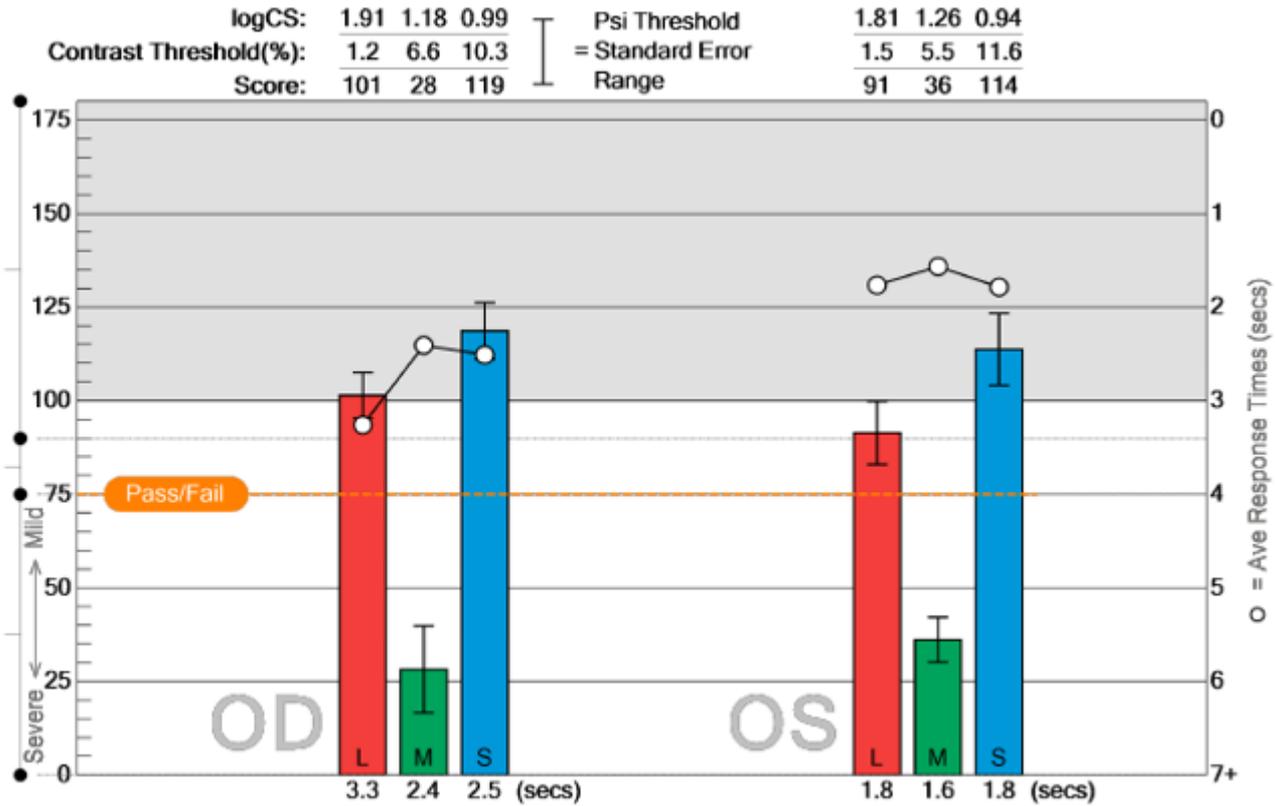
RESULTS

Normal | Typical
color vision

contrast threshold range not tested with CCT (original)

Possible
contrast sensitivity loss or acquired color deficiency

Color Vision Deficient
genetic or acquired



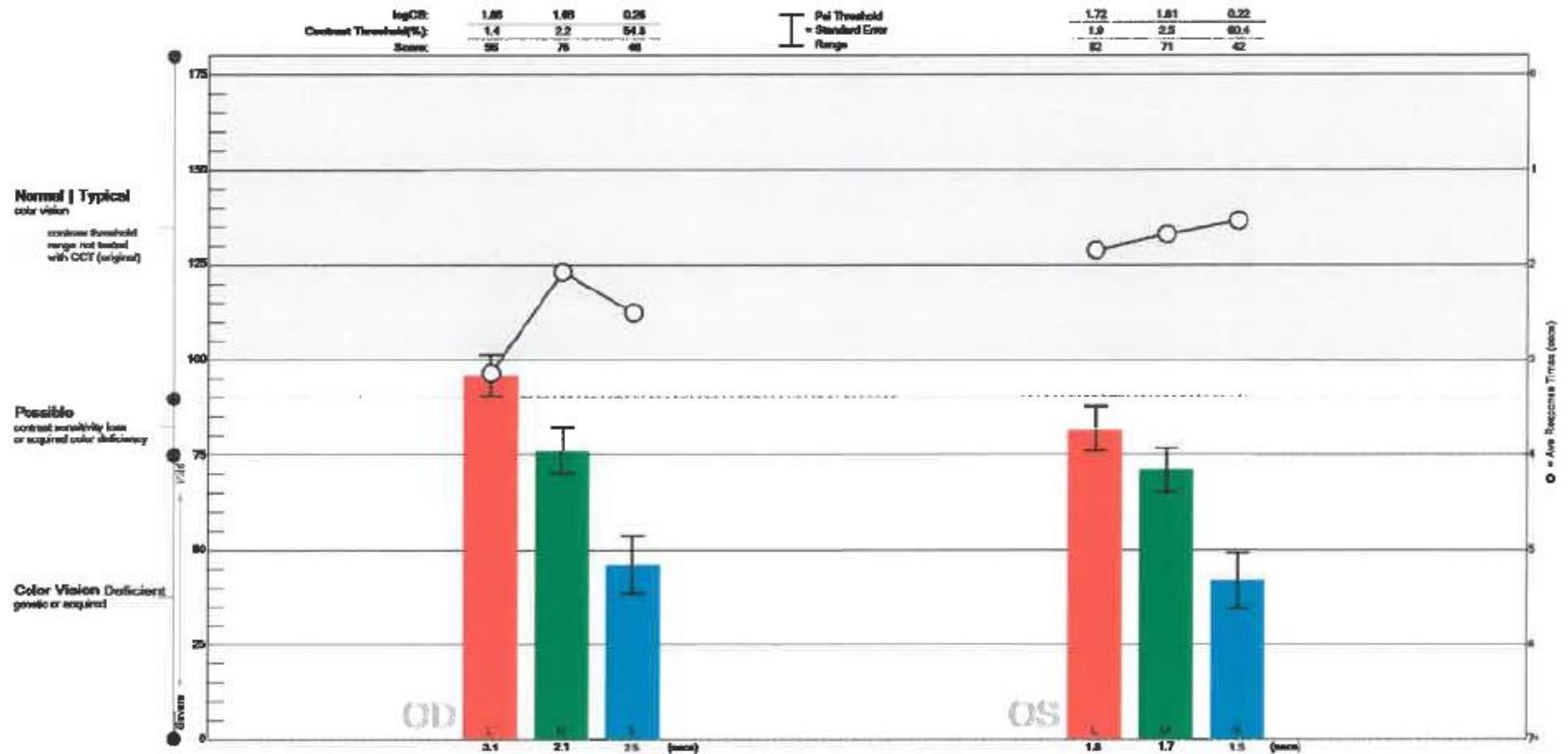
DATA

		Estimated Psi		Trials	Ave Time	Score	Category ¹
	Cone	Threshold	Error				
OD	Red L	1.2%	4.1%	30	3.3	101	Normal
	Green M	6.6%	1.7%	30	2.4	28	Severe (Deutan)
	Blue S	10.3%	2.4%	30	2.5	119	Normal
OS	Red L	1.5%	3.7%	30	1.8	91	Normal
	Green M	5.5%	4.0%	30	1.6	36	Severe (Deutan)
	Blue S	11.6%	1.8%	30	1.8	114	Normal



A Dental Professor Research in: color for reconstruction

RESULTS



E.P. 29-yo female

Experiencing loss of vision in OS with pain which lasts for several hours.

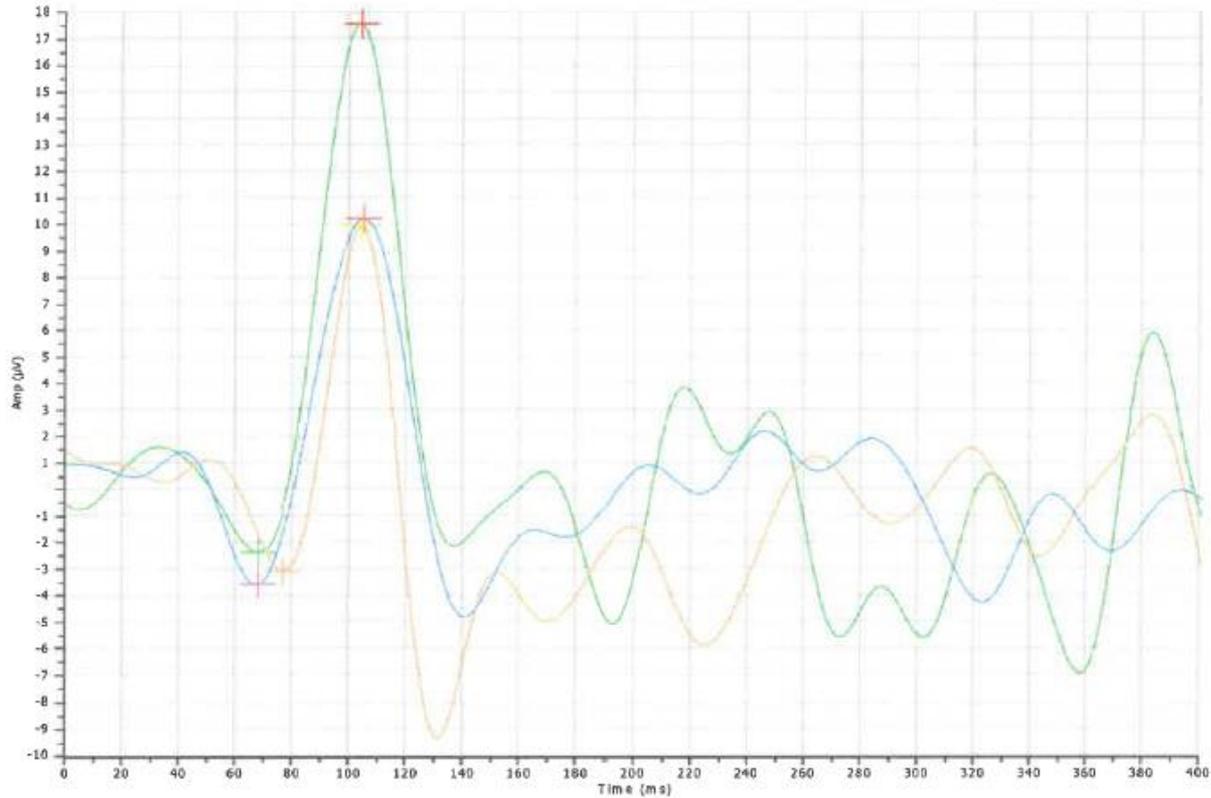
DVA OD 20/25 OS 20/25 OU 20/20

NVA OD 20/40 OS 20/30 OU 20/25

Binocular Balance: OD +0.50 -0.25 165 OS +0.50 20/20 OD, OS, OU

PRA: -3.50 NRA: +2.50

VEP's: 5 check sizes, OD, OS, OU all normal with binocular summation and no latency differences and no overall delay.



— T=20-P=16 x 16-OU-85%-C-12/12/2017 10:25:36 AM
— T=20-P=16 x 16-OD-85%-C-12/12/2017 10:28:24 AM
— T=20-P=16 x 16-OS-85%-C-12/12/2017 10:31:05 AM

		T=20-P=16 x 16-OU-85%- C-12/12/2017 10:25:36 AM	T=20-P=16 x 16-OD-85%- C-12/12/2017 10:28:24 AM	T=20-P=16 x 16-OS-85%- C-12/12/2017 10:31:05 AM
Left Cursor	Lat	68.4 ms	77.1 ms	68.4 ms
	Amp	-2.37 uV	-3.10 uV	-3.59 uV
Right Cursor	Lat	104.5 ms	104.5 ms	105.5 ms
	Amp	17.58 uV	9.94 uV	10.22 uV
Delta	Lat	36.1 ms	27.3 ms	37.1 ms
	Amp	19.95 uV	13.05 uV	13.81 uV

Houston we have a problem!

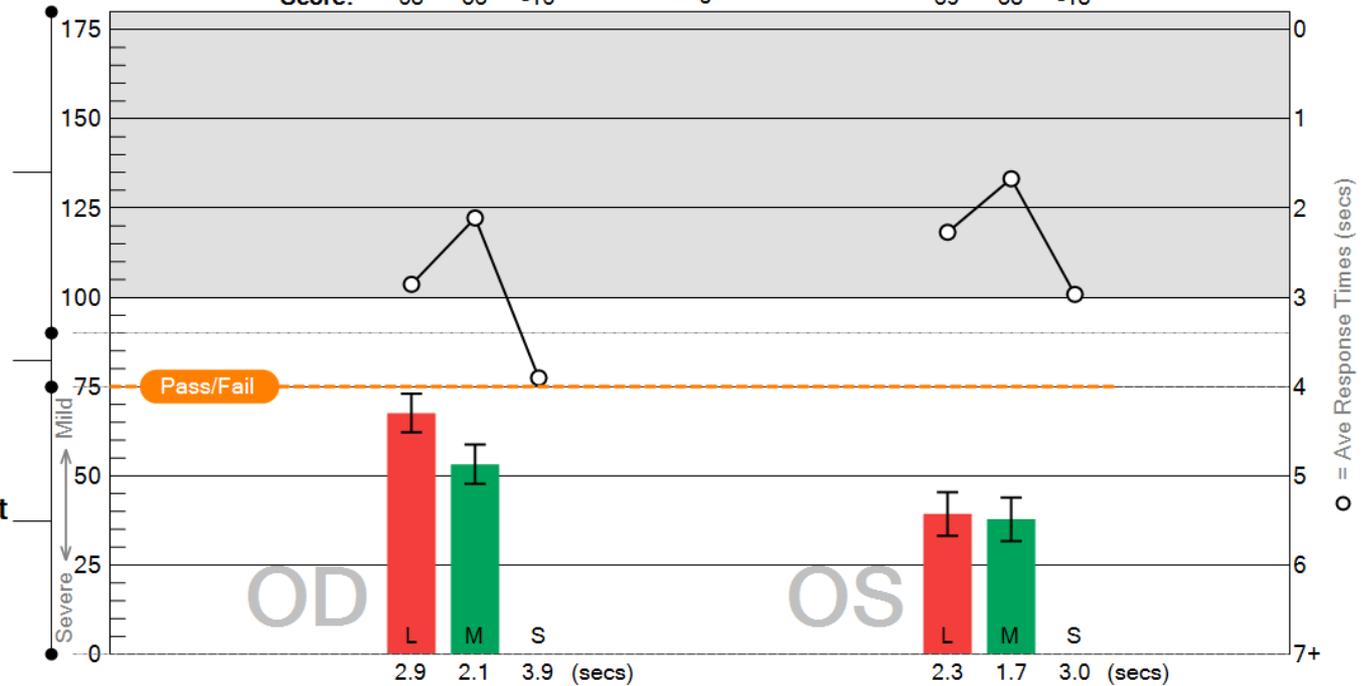
logCS:	1.58	1.43	-0.36	Psi Threshold = Standard Error Range	1.29	1.28	-0.38
Contrast Threshold(%):	2.7	3.7	229.5		5.1	5.3	241.9
Score:	68	53	-16		39	38	-18

Normal | Typical
color vision

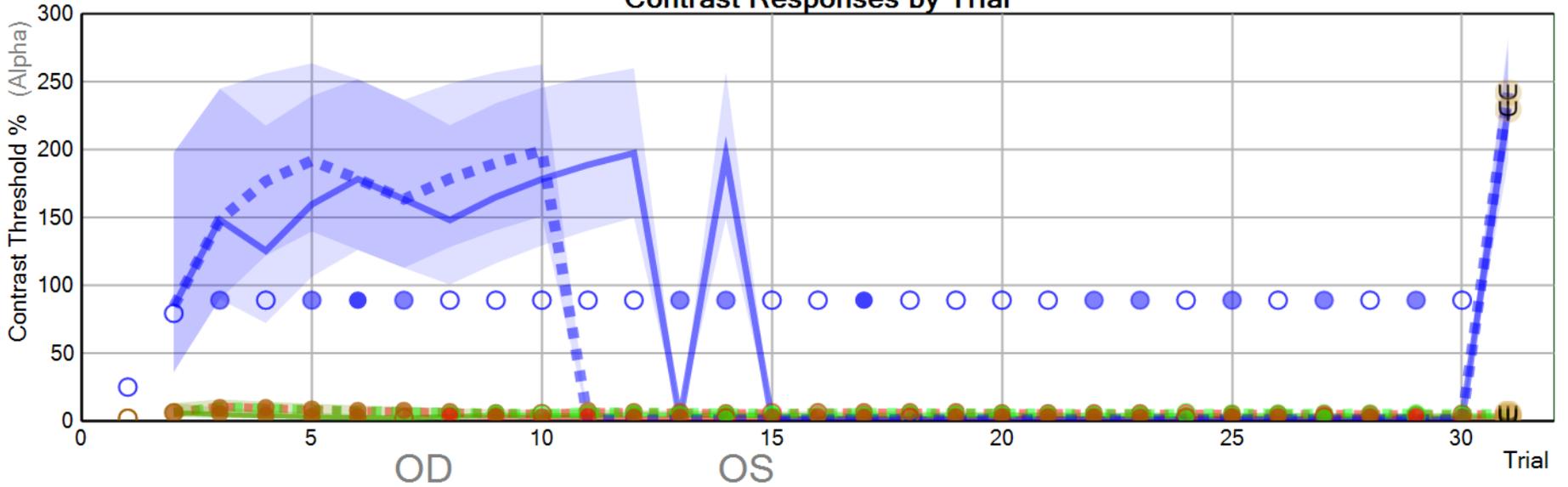
contrast threshold range not tested with CCT (original)

Possible
contrast sensitivity loss or acquired color deficiency

Color Vision Deficient
genetic or acquired

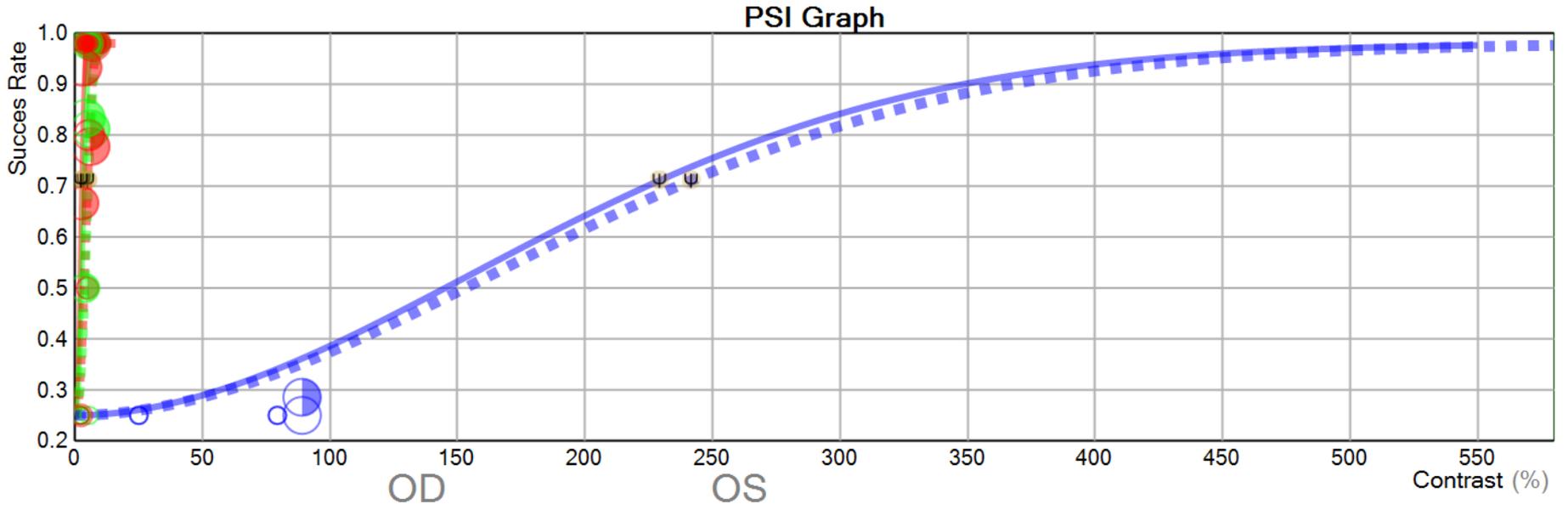


Contrast Responses by Trial



Cone	L	M	S	L	M	S
Reaction time (secs)	2.9	2.1	3.9	2.3	1.7	3.0
Contrast Threshold % (Alpha)	2.66	3.69	229.51	5.09	5.27	241.89
Standard Error (Alpha)	0.66	0.93	84.86	1.44	1.48	75.32

Show responses
 Show range
 



Cone	L	M	S	L	M	S
Reaction time (secs)	2.9	2.1	3.9	2.3	1.7	3.0
Contrast Threshold % (Alpha)	2.66	3.69	229.51	5.09	5.27	241.89
Standard Error (Alpha)	0.66	0.93	84.86	1.44	1.48	75.32

Show responses

B.C. 61-yo female

HTN since 1985, high cholesterol

1st exam at SCO: 10/27/17

DVA with Rx: OD 20/15 OS 20/15 OU 20/15

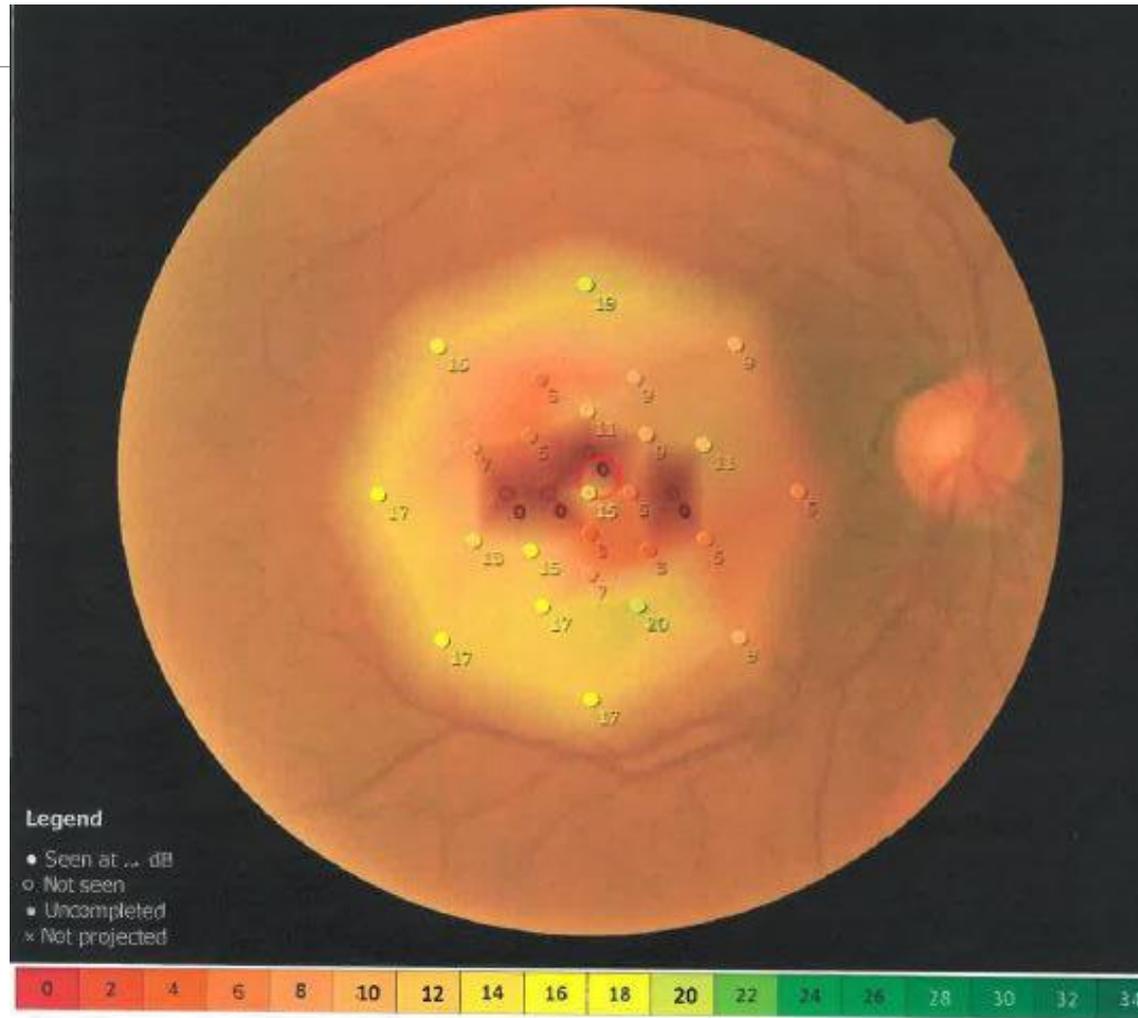
NVA with Rx: OD 20/20 OS 20/25 OU 20/25

Binocular Balance: OD +0.25 -0.50 x 59 OS +0.25 20/20 all

Brought back for DFE 11/16/17

- Scattered punched out lesions OU
- Pigmentary changes throughout
- CD OD .35/.35 OS .65/.65
- 24-2 OD ok - possible arcuate superior OS

Nidek Micro-Perimeter



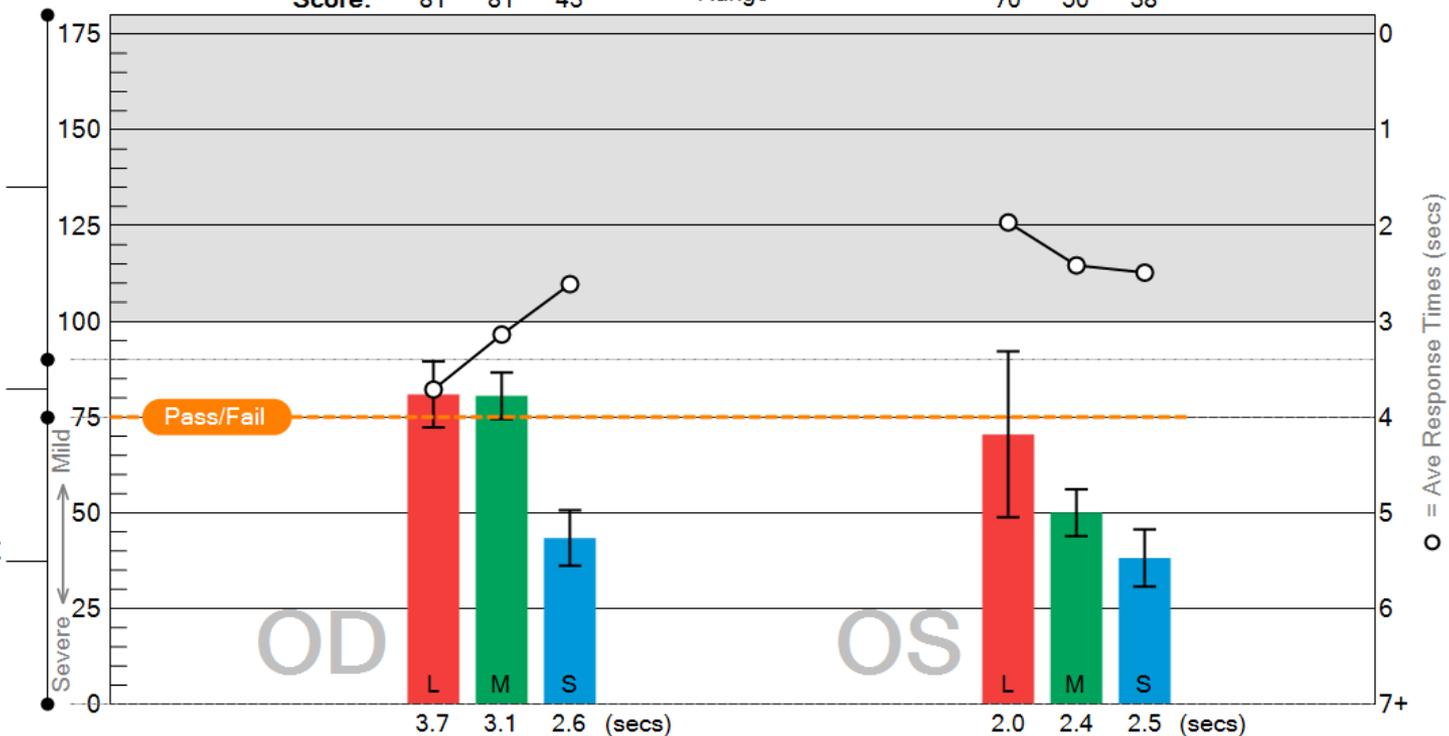
logCS:	1.71	1.71	0.23	Psi Threshold = Standard Error Range	1.60	1.40	0.18
Contrast Threshold(%):	2.0	2.0	58.4		2.5	4.0	65.8
Score:	81	81	43		70	50	38

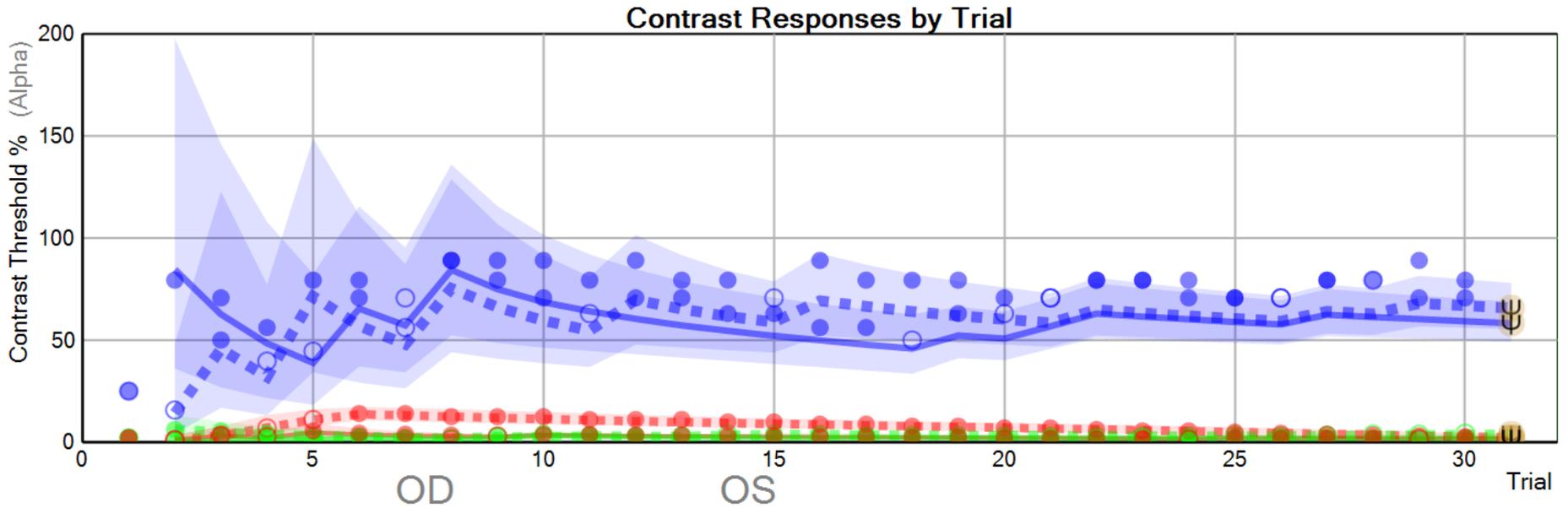
Normal | Typical
color vision

contrast threshold
range not tested
with CCT (original)

Possible
contrast sensitivity loss
or acquired color deficiency

Color Vision Deficient
genetic or acquired





Cone	<u>L</u>	<u>M</u>	<u>S</u>	<u>L</u>	<u>M</u>	<u>S</u>
Reaction time (secs)	3.7	3.1	2.6	2.0	2.4	2.5
Contrast Threshold % (Alpha)	1.95	1.97	58.35	2.48	3.98	65.78
Standard Error (Alpha)	0.78	0.55	19.54	2.58	1.12	22.62

 Show responses

 Show range


58-yo male

9/7/17 sent in by outside OD

Type 2 diabetic – elevated A1C in June 7.3% - on steroid for pneumonia
– BP 140/88

DVA with Rx: OD 20/15-3 OS 20/15-1 OU 20/15-2

NVA with Rx: 20/25+ all

ASEG – nothing interesting

PSEG OD shows Drusen scattered but not in OS.

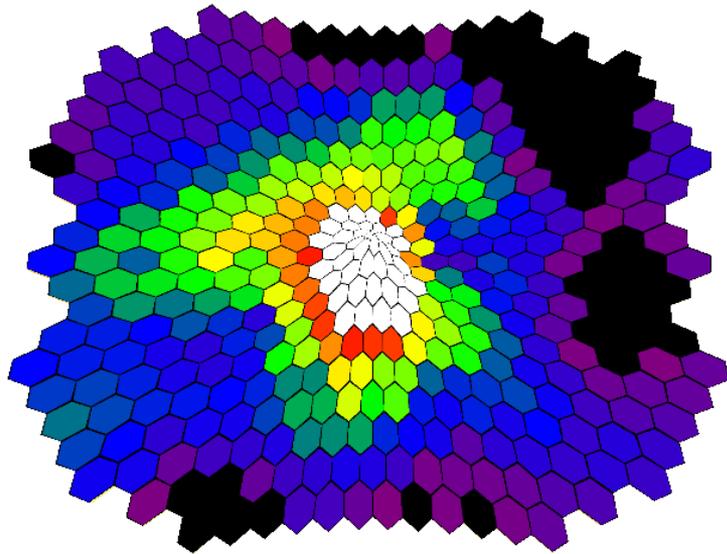
NOTES: OD appears like intermediate AMD. 2nd opinion by another doctor: Could be CACD but very asymmetric. Spectralis shows choroidal irregularity and Drusen affecting the RPE layer.

Multi focal ERG

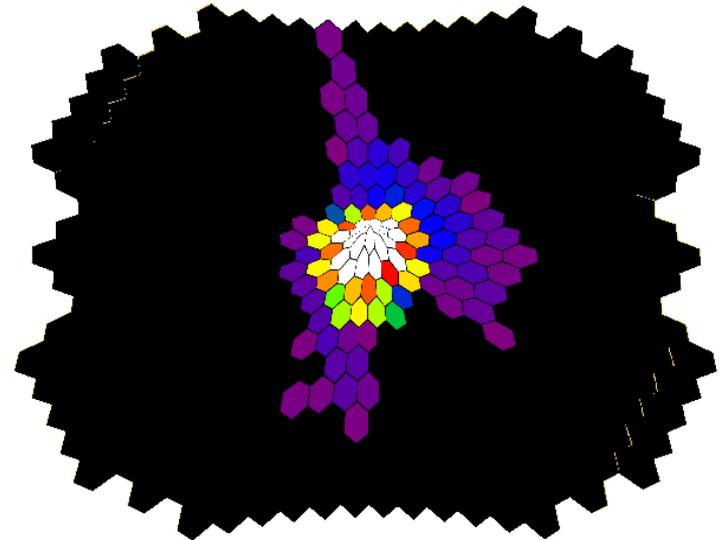
OD

OS

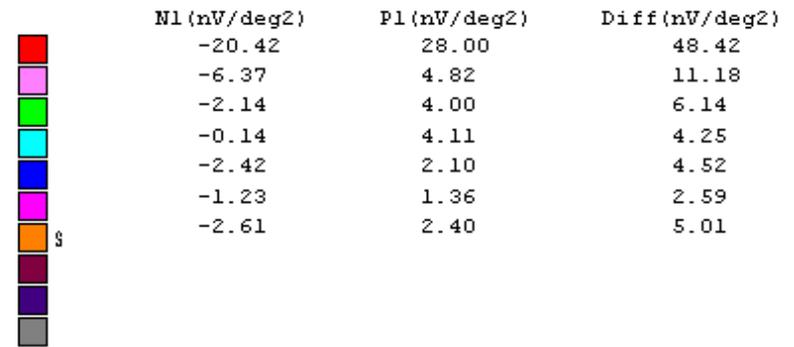
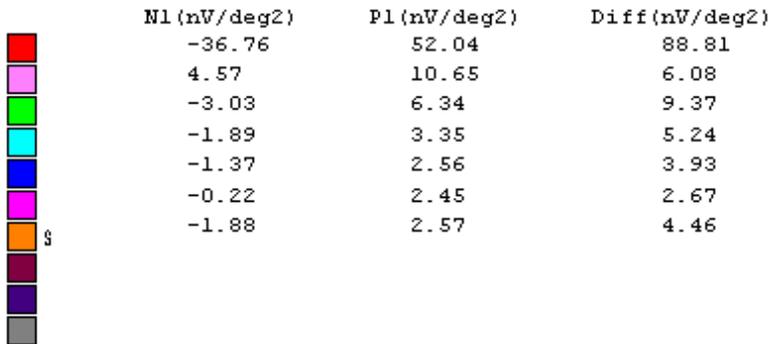
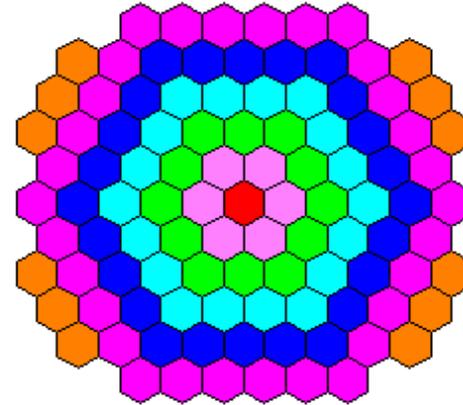
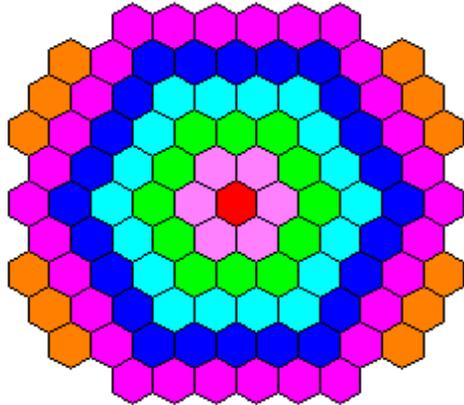
R (40)



L (41)

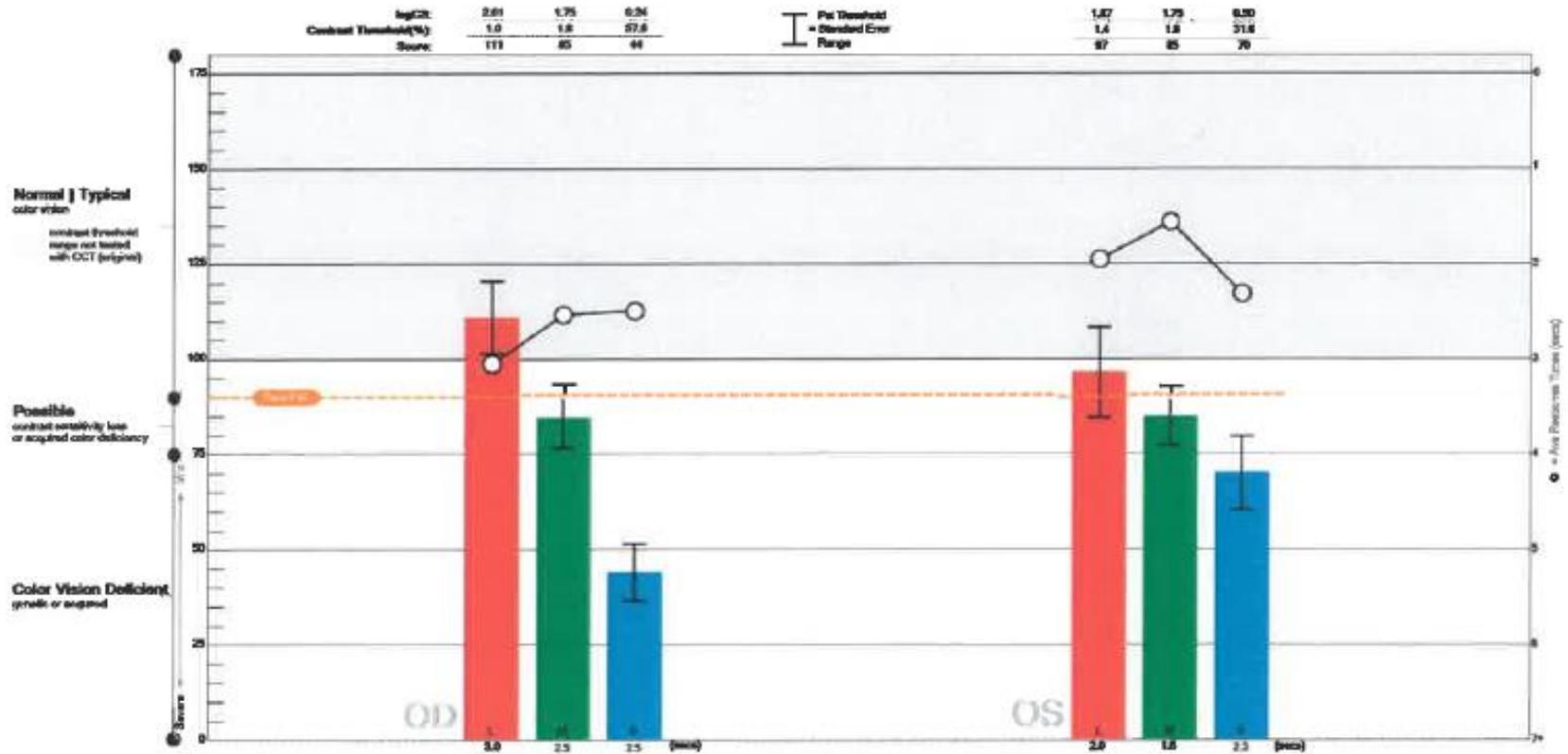


mfERG Ring Analysis



ColorDx CCT-HD Results

RESULTS



CCT-HD Data

CCT^{HD}™

DATA

	Cone	Psi Threshold	Trials	Ave Time	Score	Category ¹
OD	Red L	1.0%	30	3.0	111	Normal
	Green M	1.8%	30	2.5	85	Possible (Deutan)
	Blue S	57.6%	30	2.5	44	Color Deficient (Tritan)
OS	Red L	1.4%	30	2.0	97	Normal
	Green M	1.8%	30	1.6	85	Possible (Deutan)
	Blue S	31.6%	30	2.3	70	Color Deficient (Tritan)

Historical Methods: Lower Sensitivity and Specificity

The opportunity is to augment clinical data with a new test of vision function assessing cone function.

100s of Substances and Pharmaceutical Agents Can Cause Color Vision Defects

acetohexamide
adrenal cortex injection
alcohol
amobarbital
aspirin
atropine
beclomethasone
betamethasonebroxyquinolone
butalbital
carbamazepine
carbon dioxide
cataracts
chloramphenicol
chloroquine
chlorpromazine
chlorpropamide
cimetidine
cisplatin
cortisone
deferoxamine
denileukin diftitox
dexamethasone
diabetes
dicyclomine
diiodohydroxyquinoline
dimethyl sulfoxide
disulfiram
dronabinol
epinephrine
ergometrine
ergotamine tartrate
erythromycin
estradiol
**estrogen &
progesterone
combo products**

ethambutol
ethionamide
famotidine
fludrocortisone
fluorometholone
uphenazine
glaucoma
glibenclamide
glimepiride
glipizide
glycopyrrolate
griseofulvin
hashish
herbal medicines
homatropine
hydrocortisone
hydroxychloroquine
ibuprofen
indometacin
influenza virus vaccine
iodide and iodine solutions &
compounds
isocarboxazid
isoniazid
isotretinoin
lidocaine
linezolid
idlorazepam
LSD
marijuana
medrysone
mepacrine
mepenzolate
mercaptapurine

mescaline
methazolamide
methohexital
methylergometrine maleate
methylphenobarbital
methylprednisolone
metoclopramide
metronidazole
multiple sclerosis
nalidixic acid
naproxen
nitrofurantoin
nizatidine
norepinephrine
organophosphates
oxazepam
pamidronate
penicillamine
pentobarbital
perphenazine
phenelzine
phenobarbital
phenytoin
physostigmine
pilocarpine
pioglitazone
piperazine
prednisolone
prednisone
primidone
prochlorperazine
promethazine
propantheline
psilocybin
pyridostigmine
quinidine
quinine
radioactive iodides

rrantidine
escinnamine
reserpine
quinine
radioactive iodides
rantidine
rescinnamine
reserpine
rifampicin
rimexolone
rosiglitazone
secbutalbarbital
secobarbital
sildenafil (Viagra)
sulfacetamide
sulfafurazole
sulfamethizole
sulfamet1oxazole
sulfanilamide
sulfasalazine
sulfathiazole
sulfathiazole
sulfathiazole
sulfathiazole
tamoxifen
thiabendazole
thietilperazine
thioacetazone
tlioridazine
tioguanine
tobramycin
tolazamide
tolbutamide
tolterodine
tranexamic acid
tranylcypromine
triamcinolone
vardenafil
vigabatrin
vincristine
voriconazole
walianin
zidovudine

Source: Fraunfelder, Fraunfelder, Chambers. Clinical Ocular Toxicology. Sanders Elsevier, 2008: 320. Available for purchase at: [Elsevier](#) and [Amazon](#). Please reference Clinical Ocular Toxicology for categorization of color vision defects by certain, probable, possible, or conditional/unclassified. Emphasis above added to highlight common substances often neglected in relationship to acquired color vision defects.

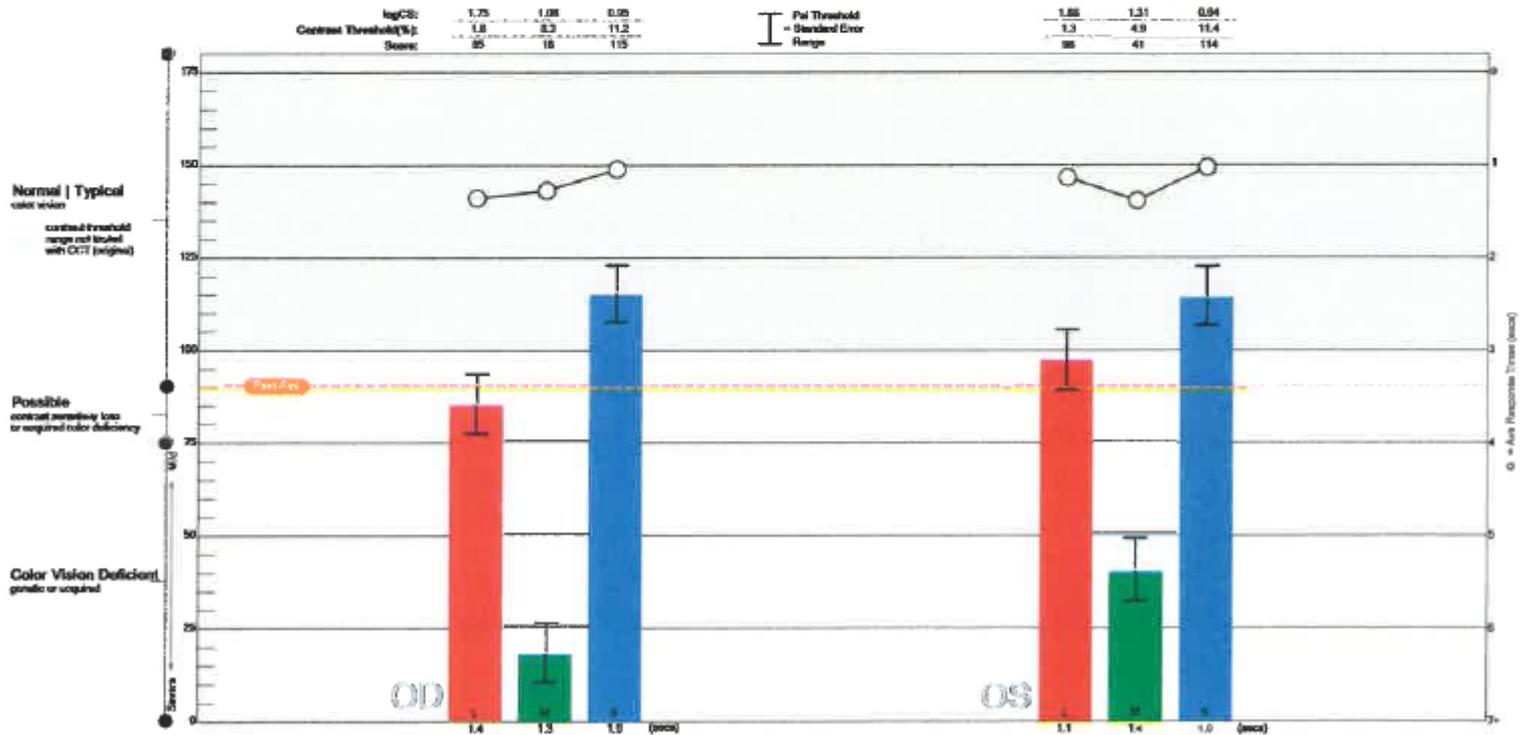
How about some
vanilla color
deficiencies?

DATA

	Cone	Psi Threshold	Trials	Ave Time	Score	Category ¹
OD	Red L	1.8%	30	1.4	85	Possible
	Green M	8.3%	30	1.3	18	Color Deficient
	Blue S	11.2%	30	1.0	115	Normal
OS	Red L	1.3%	30	1.1	98	Normal
	Green M	4.9%	30	1.4	41	Color Deficient
	Blue S	11.4%	30	1.0	114	Normal

¹Cut-off criteria are physician-selected from custom, or user input score method ranges and corresponding assigned categories.

RESULTS

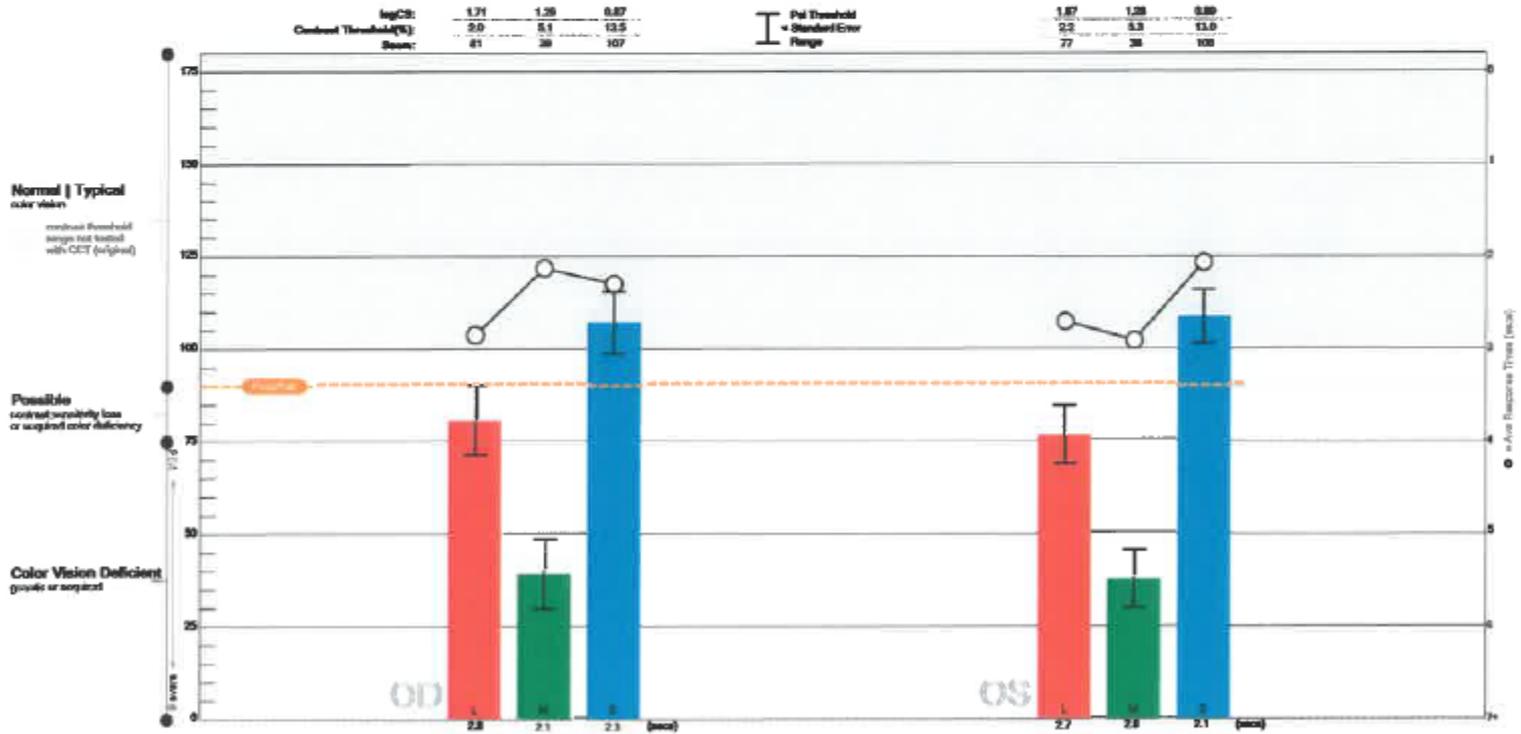


DATA

	Cone	Psi Threshold	Trials	Ave Time	Score	Category ¹
OD	Red L	2.0%	30	2.8	81	Possible
	Green M	5.1%	30	2.1	39	Color Deficient
	Blue S	13.5%	30	2.3	107	Normal
OS	Red L	2.2%	30	2.7	77	Possible
	Green M	5.3%	30	2.9	38	Color Deficient
	Blue S	13.0%	30	2.1	109	Normal

¹Cut-off criteria are physician-selected from custom, or user input score method ranges and corresponding assigned categories.

RESULTS



Billing and Diagnosis Codes

Extended Color Testing: 92283
approximately \$65

- Deutan H53.53
- Protan H53.54
- Tritan H53.55

Questions & Answers

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