CIE-CORM 2019

Session VIII – Vision and Colour

Assessing color disagreement due to diversity in spectral sensitivity functions

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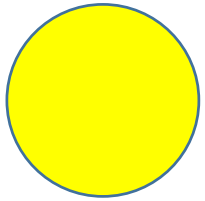
Wednesday October 30, 2019

Assessing Color Disagreement Due to Diversity in Spectral Sensitivity Functions

What does color *agreement* mean?



Most people see this color the same way?

Actually, we can’t really know that.

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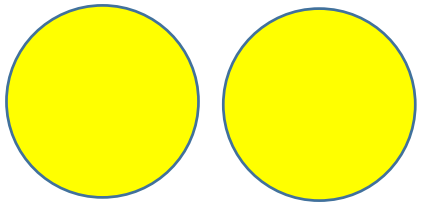
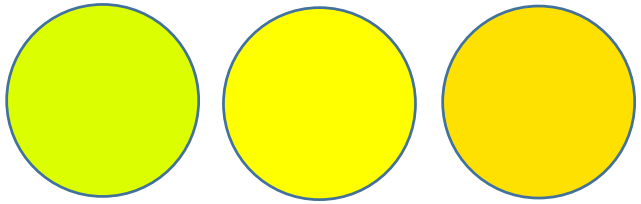


Most people agree these colors match?

Yes, that’s the easy form of agreement.

Assessing Color Disagreement Due to Diversity in Spectral Sensitivity Functions

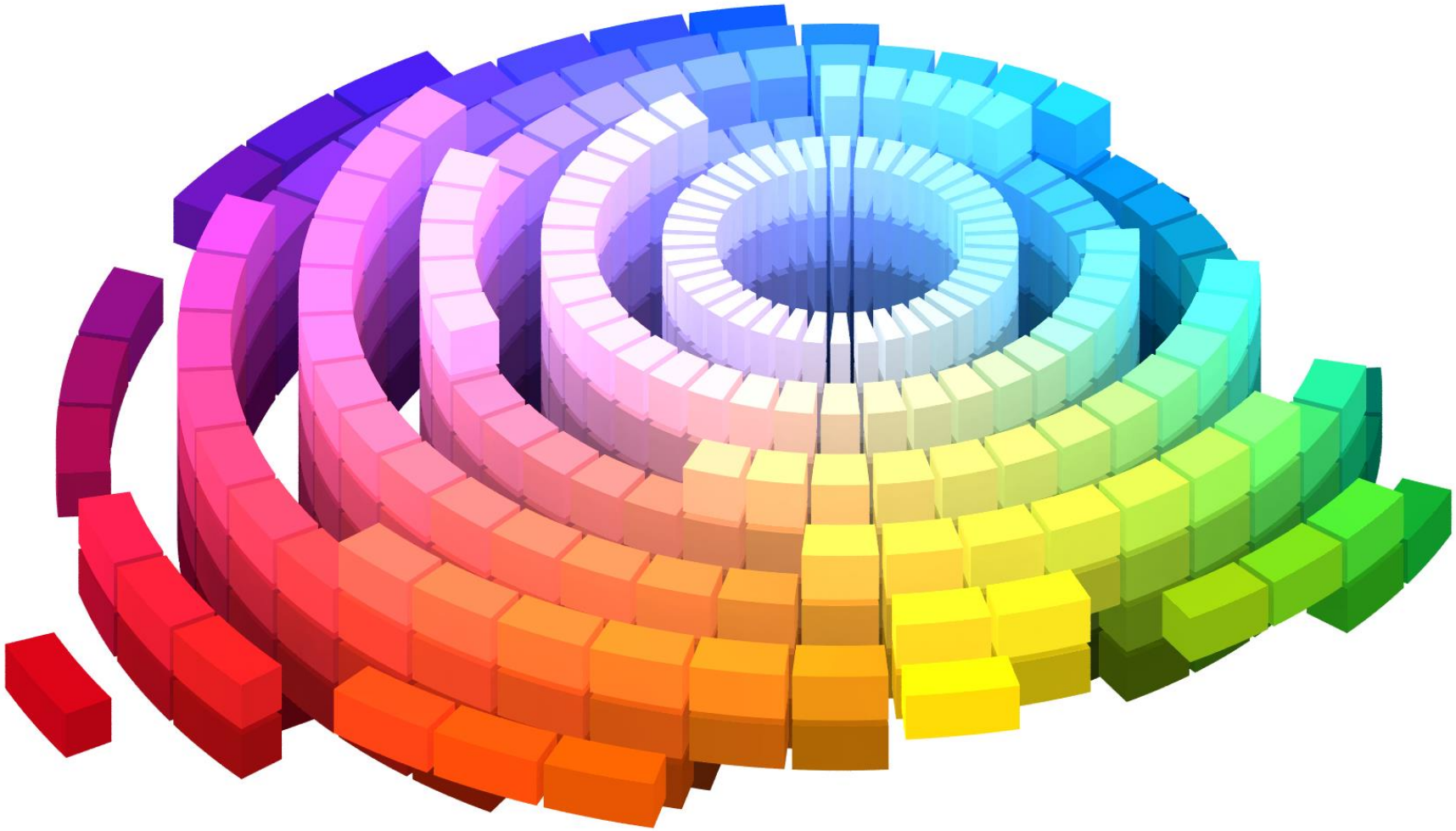
What does color *agreement* mean?



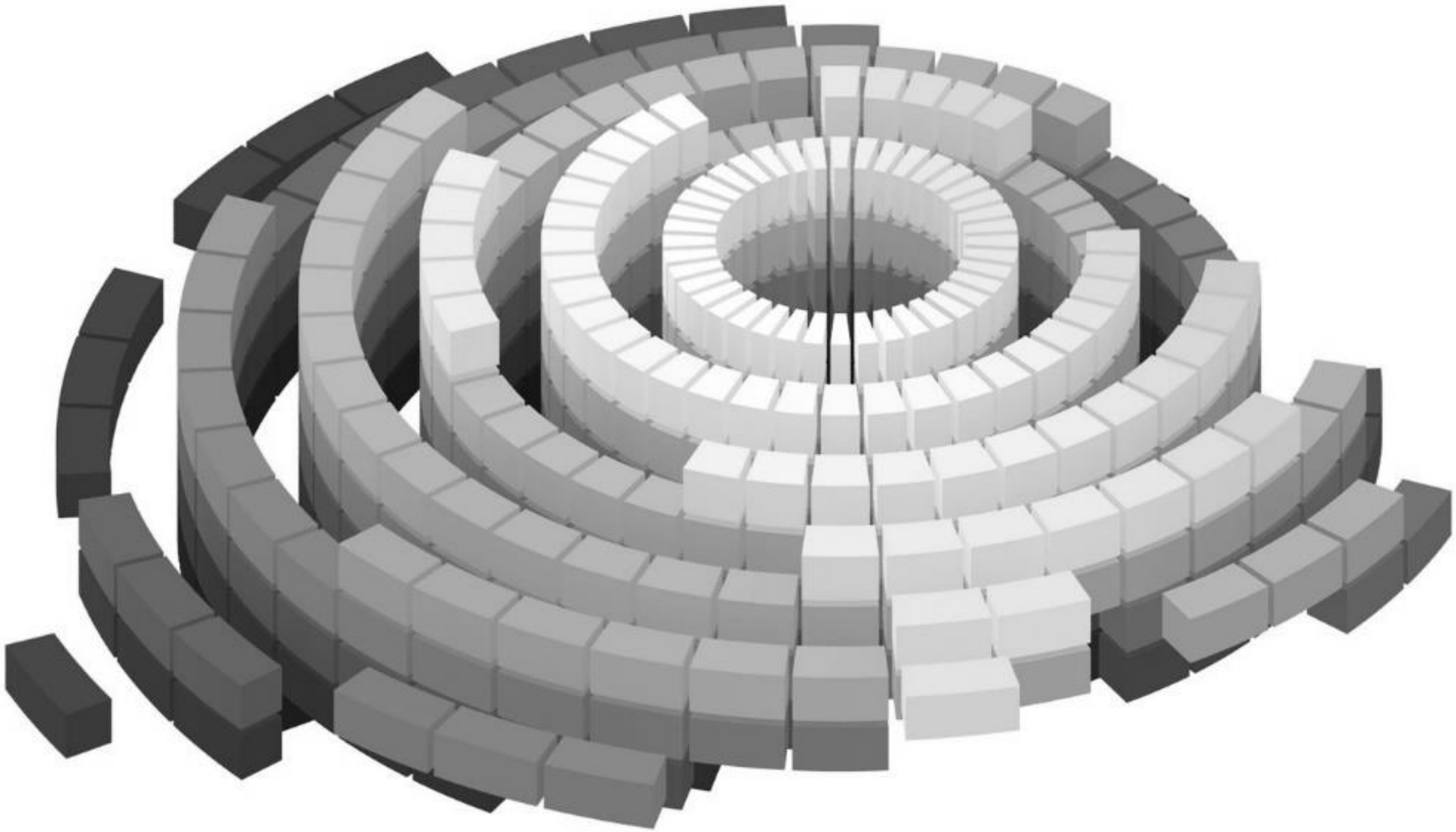
Most people agree these colors differ equally?

Yes, that’s also an important form of agreement.

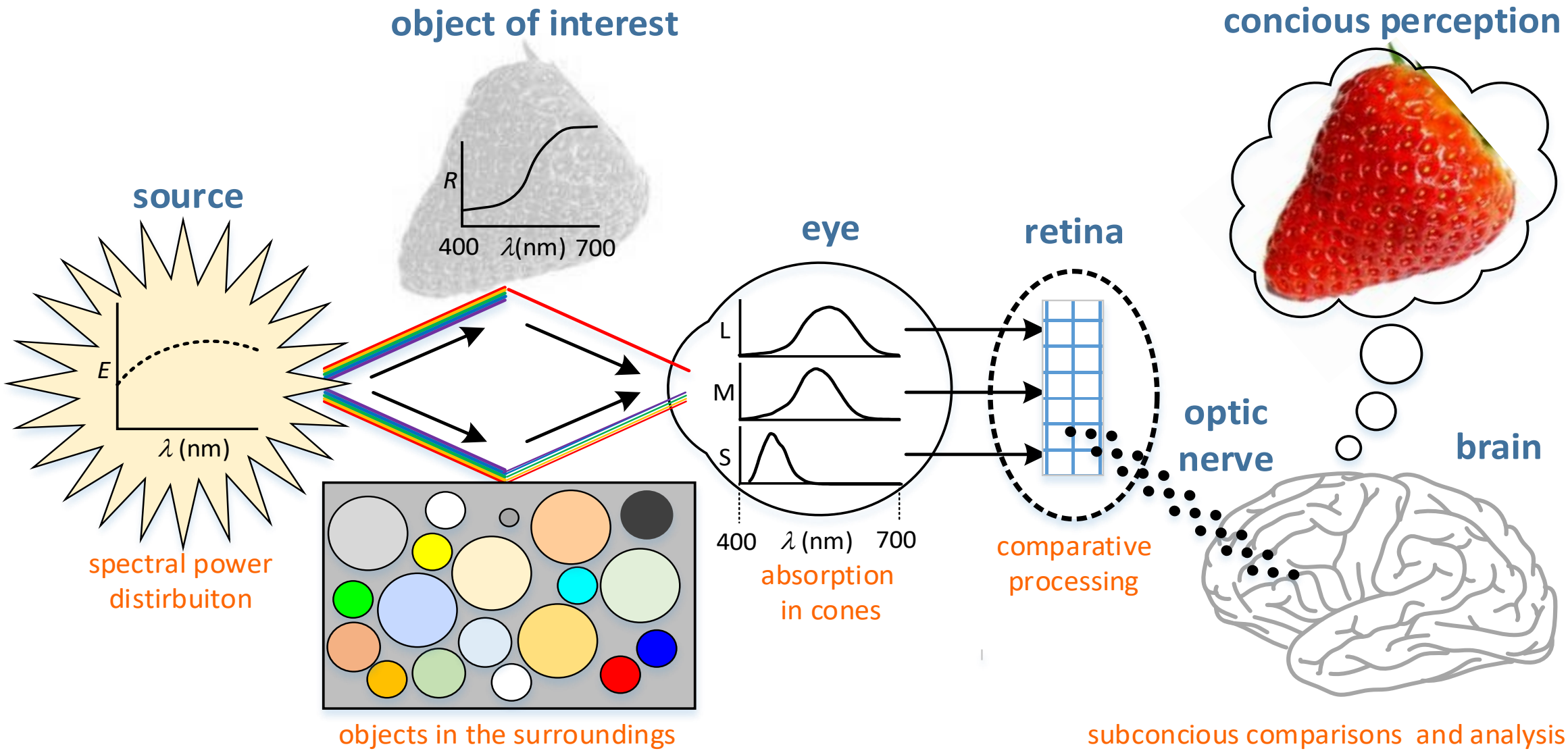
Understanding Perception of Surface Colors



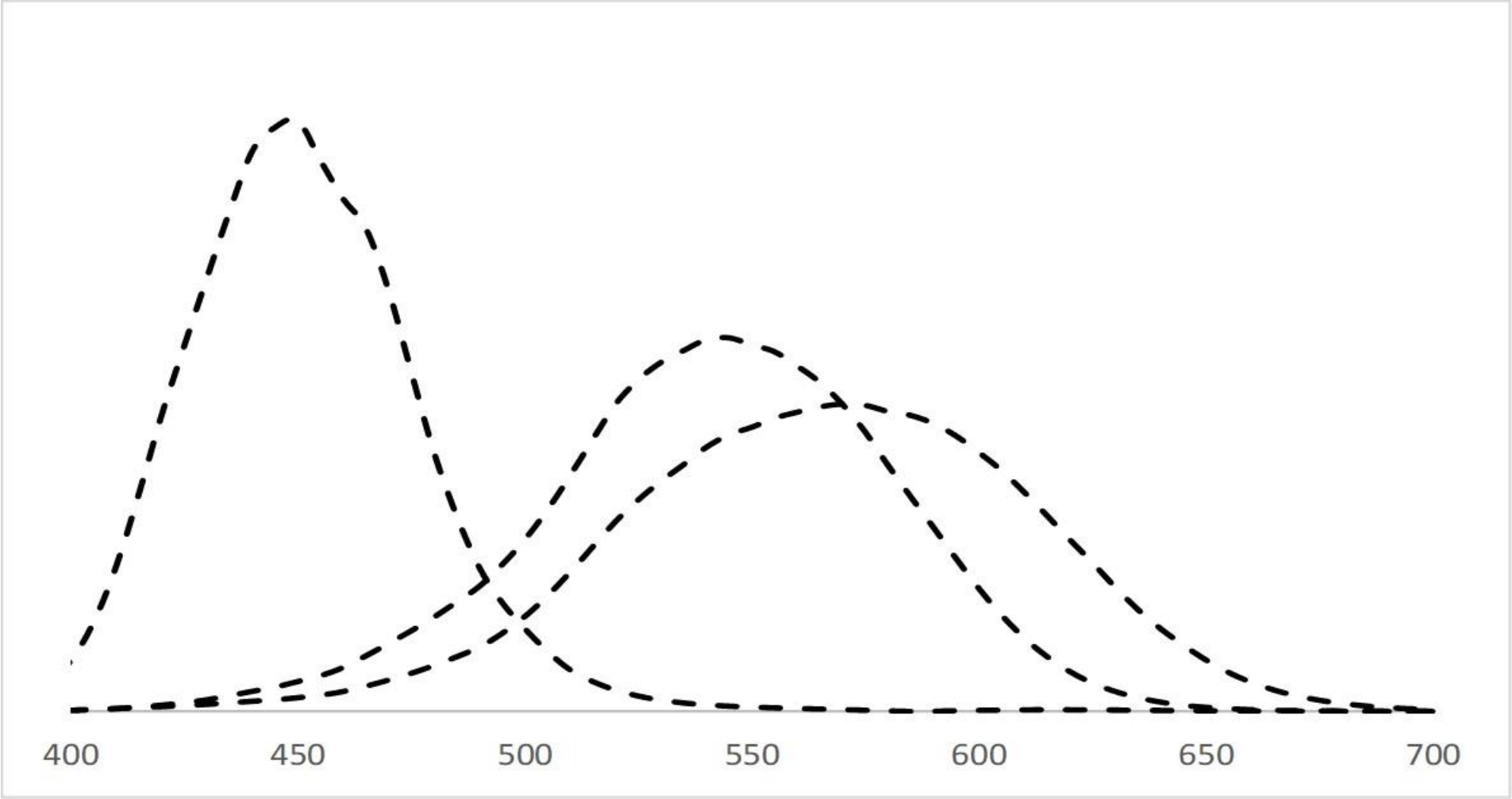
Understanding Perception of Surface Colors



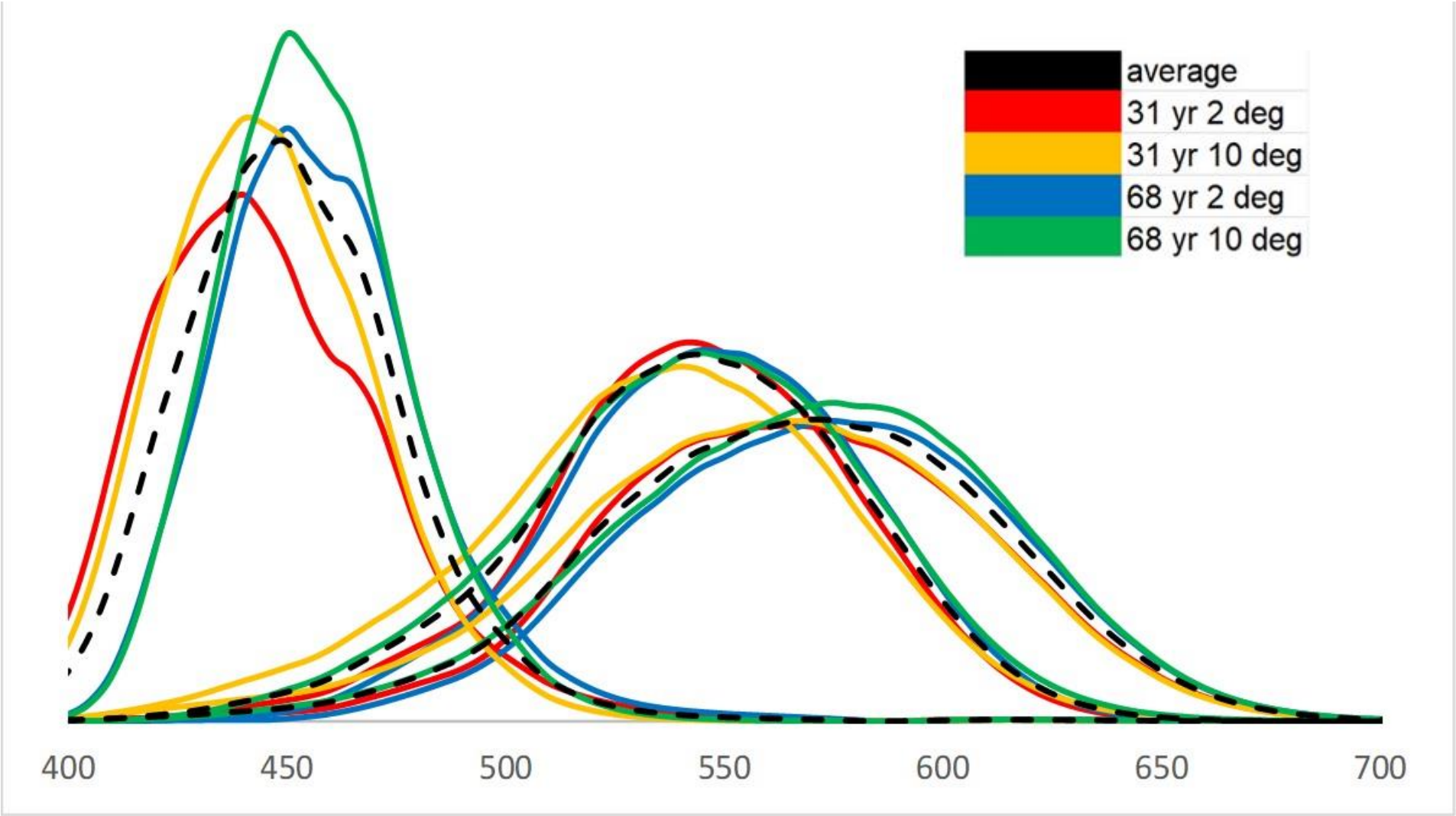
Understanding Perception of Surface Colors



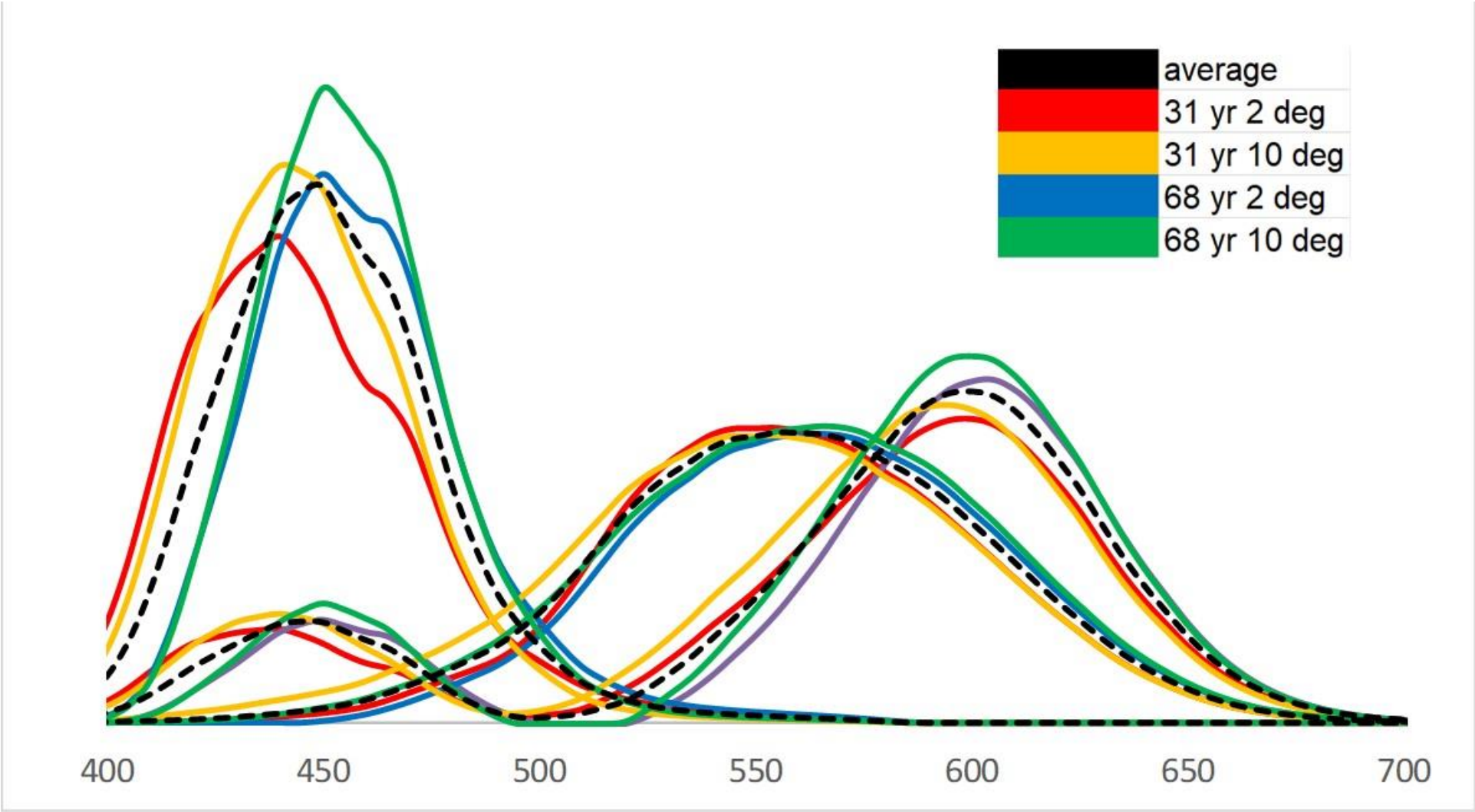
Human Cone Fundamentals



Human Cone Fundamentals - Diversity



Color Matching Functions - Diversity



Recent Papers on Retinal Diversity and Adaptation:

Lucassen M, Borra T, Souman J, Schlangen L. **Maxwell's spot measurements in changing white light spectra.** Journal of Vision. 2017 Sep 1;17(10):647-.

Murdoch MJ, Fairchild MD. **Modelling the effects of inter-observer variation on colour rendition.** Lighting Research & Technology. 2019 Jan;51(1):37-54.

Smet KA, Webster MA, Whitehead LA. **A simple principled approach for modeling and understanding uniform color metrics**. JOSA A. 2016 Mar 1;33(3):A319-31.

Webster MA, Juricevic I, McDermott KC. **Simulations of adaptation and color appearance in observers with varying spectral sensitivity**. Ophthalmic and Physiological Optics. 2010 Sep;30(5):602-10.

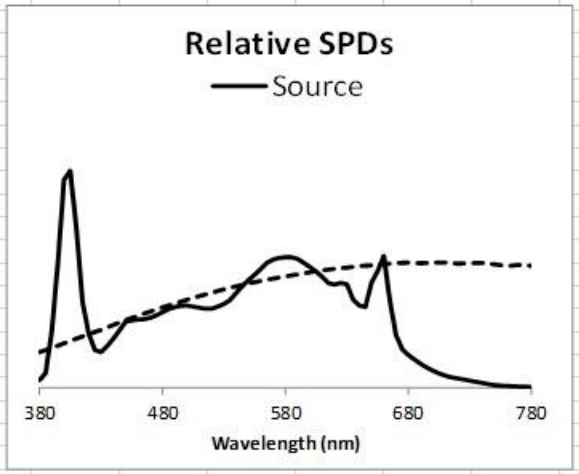
Chromaticity Shifts due to Retinal Diversity

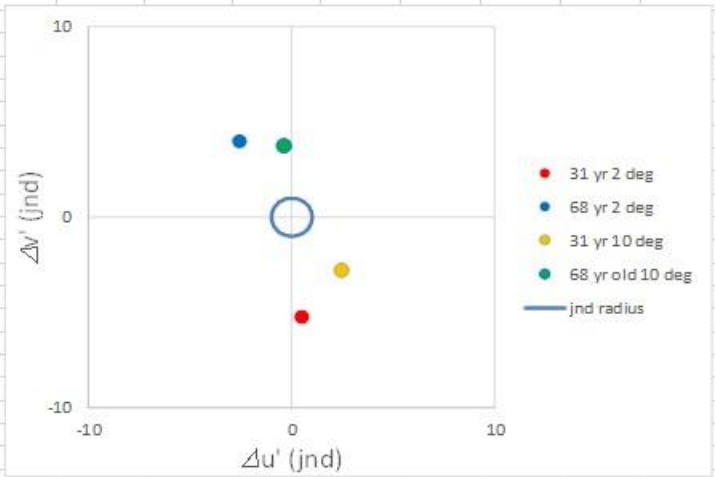
Calculator for Chromaticity Shifts due to Retinal Diversity

Wavelength (nm)	Source SPD	Reference SPD
380	0.036213	0.317
381	0.042788	0.321
382	0.049363	0.325
383	0.055937	0.328
384	0.062512	0.332
385	0.069087	0.336
386	0.10721	0.339
387	0.14534	0.343
388	0.18346	0.347
389	0.22159	0.351
390	0.25971	0.354
391	0.32354	0.359
392	0.38737	0.363
393	0.4512	0.367
394	0.51503	0.371
395	0.57886	0.375
396	0.65495	0.380
397	0.73105	0.384
398	0.80715	0.388
399	0.88324	0.392
400	0.95934	0.396
401	0.96747	0.401
402	0.97561	0.405
403	0.98374	0.409
404	0.99187	0.413
405	1	0.417
406	0.94768	0.421
407	0.89535	0.425
408	0.84303	0.429
409	0.79071	0.433
410	0.73838	0.437
411	0.67047	0.441
412	0.60256	0.445
413	0.53465	0.449
414	0.46674	0.453
415	0.39883	0.457
416	0.36948	0.461
417	0.34013	0.465
418	0.31078	0.469
419	0.28143	0.473
420	0.252	0.477
421	0.23688	0.481
422	0.22168	0.485
423	0.20648	0.488
424	0.19128	0.492
425	0.17608	0.496

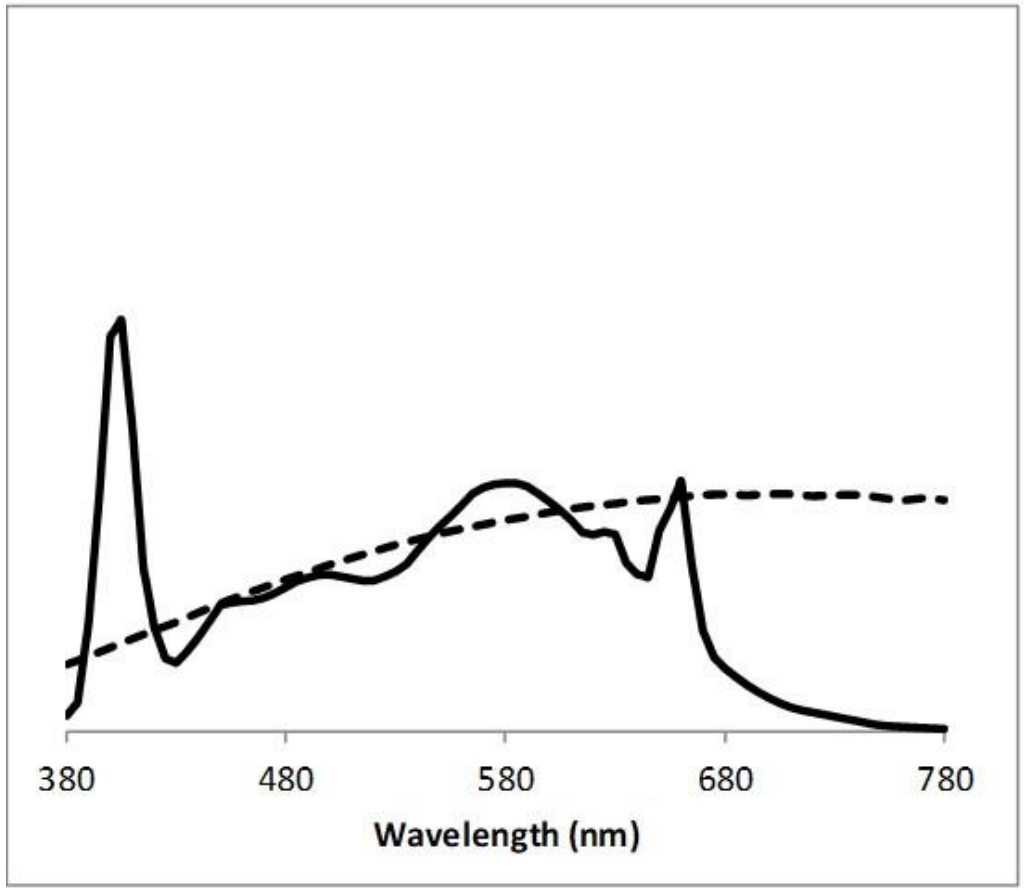
	CCT (K)	Duv	LER (lm/W	Rf	Rd
	4052	0.0034	266.9	89.8	78.1

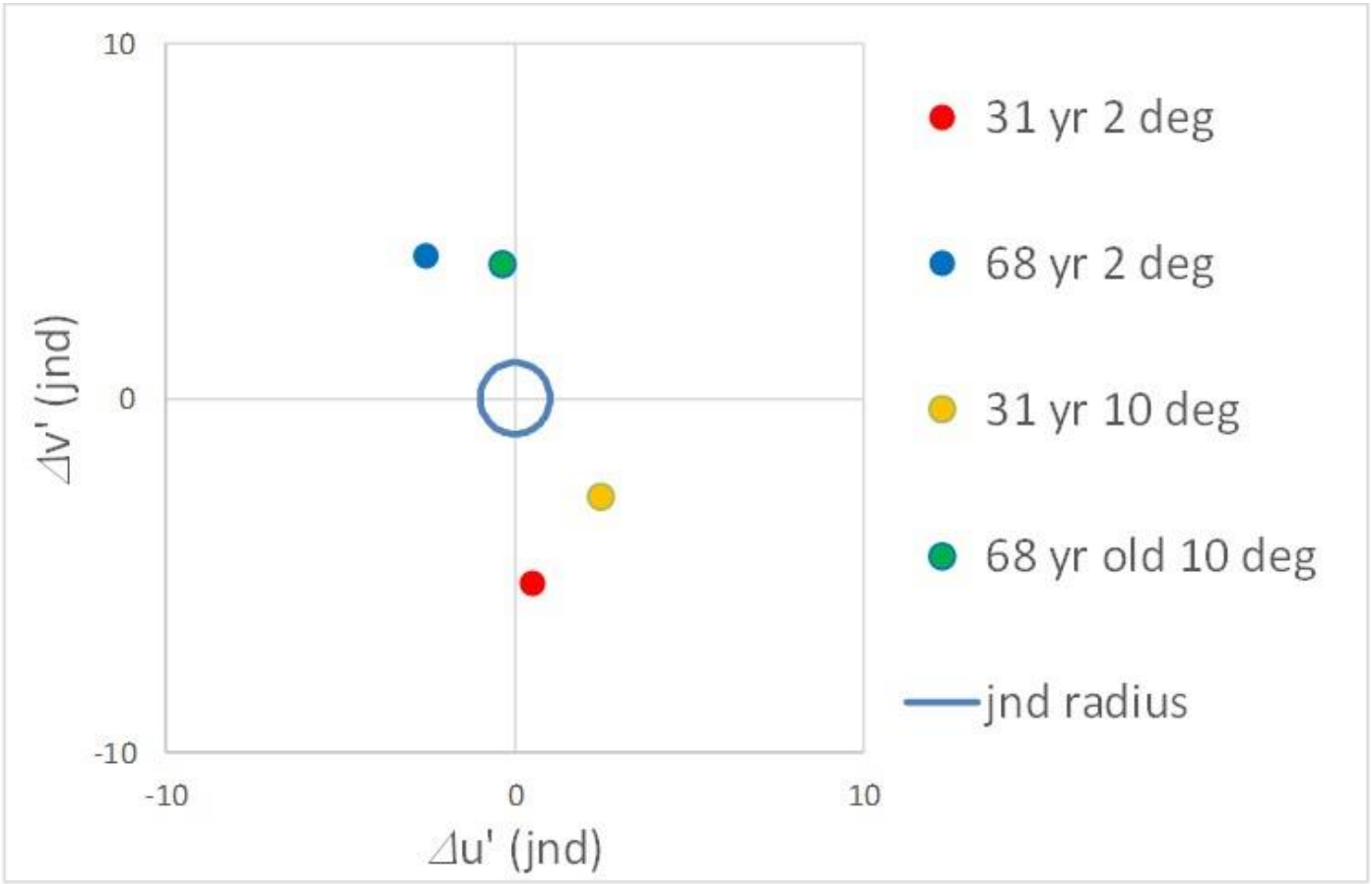
	31 yr old 2 degree			68 yr old 2 degree			31 yr old 10 degree			68 yr old 10 degree			average 31/68 2/10		
Source	X-31-2	Y-31-2	Z-31-2	X-68-2	Y-68-2	Z-68-2	X-31-10	Y-31-10	Z-31-10	x-68-10	Y-68-10	Z-68-10	Xave	Yave	Zave
	51.971	51.846	36.121	51.786	52.720	33.178	55.973	54.905	36.384	56.495	56.466	34.597	54.056	53.984	35.070
	x-31-2	y-31-2		x-68-2	y-68-2		x-31-10	y-31-10		x-68-10	y-68-10		x-68-10	y-68-10	
	0.371385	0.370493		0.376122	0.382908		0.38009	0.372838		0.382865	0.38267		0.37772	0.37722	
	u'-31-2	v'-31-2		u'-68-2	v'-68-2		u'-31-10	v'-31-10		u'-68-10	v'-68-10		u'-68-10	v'-68-10	
	0.222	0.497		0.220	0.504		0.226	0.500		0.224	0.505		0.223	0.501	
Reference	X-31-2	Y-31-2	Z-31-2	X-68-2	Y-68-2	Z-68-2	X-31-10	Y-31-10	Z-31-10	X-68-10	Y-68-10	Z-68-10	Xave	Yave	Zave
	99.859	100.188	63.608	103.013	101.798	68.923	107.514	106.524	67.598	111.431	109.355	72.295	105.454	104.466	68.106
	x-31-2	y-31-2		x-68-2	y-68-2		x-31-10	y-31-10		x-68-10	y-68-10		x-68-10	y-68-10	
	0.378748	0.379997		0.376326	0.371886		0.381748	0.378233		0.380206	0.37312		0.3793	0.37574	
	u'-31-2	v'-31-2		u'-68-2	v'-68-2		u'-31-10	v'-31-10		u'-68-10	v'-68-10		u'-68-10	v'-68-10	
	0.223	0.503		0.224	0.499		0.225	0.502		0.226	0.500		0.225	0.501	
Diff	-0.001	-0.005		-0.004	0.005		0.001	-0.003		-0.002	0.005		-0.002	0.000	
Ddiff	0.001	-0.006		-0.003	0.004		0.003	-0.003		0.000	0.004		0.000	0.000	
JND	0.5	-5.2		-2.6	4.0		2.5	-2.8		-0.4	3.8				
vsumJND	5.2			4.8			3.7			3.8					
aveJND	4.4														



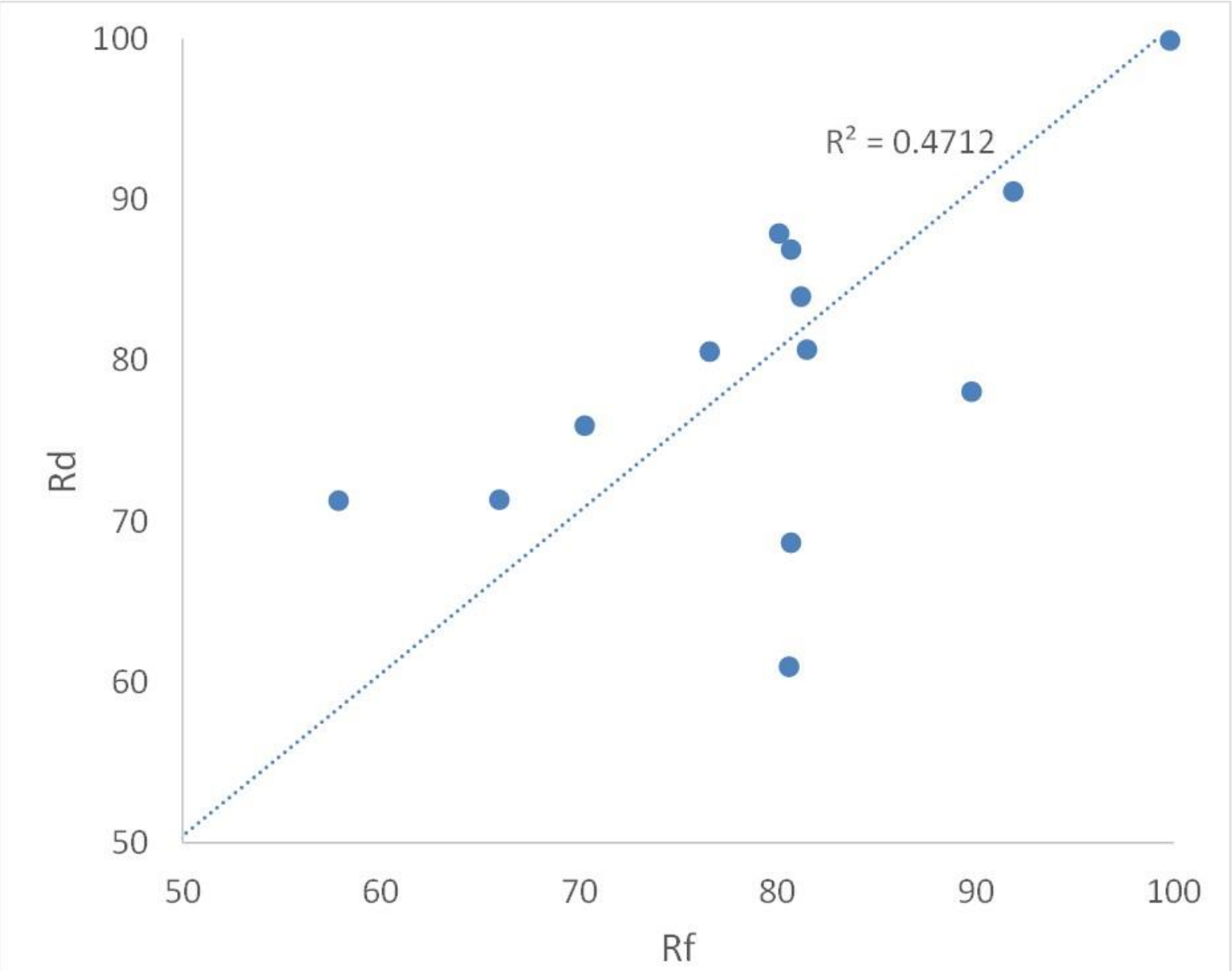


Chromaticity Shifts due to Retinal Diversity





Chromaticity Errors vs Color Fidelity Errors



Assessing color disagreement due to diversity in spectral sensitivity functions

- Significant visual processing enables color agreement despite the diversity of spectral sensitivity functions with normal observers
- However, when an illumination SPD differs substantially from daylight, the erroneous color differences cannot be “adapted away”
- This problem is likely exacerbated by illuminant spectra with strong narrowband spectral features
- We propose to quantify this problem within the calculation system of IES TM-30, using sets of individual sensitivity functions
- Goal – a metric for the “diversity tolerance”, for monochrome and color viewing, chromaticity shifts, and color rendering shifts