EnergyMed 13ª edizione

Mostra Convegno sulle Fonti Rinnovabili e l'Efficienza Energetica nel Mediterraneo

LUCE E SOSTENIBILITÀ AMBIENTALE:

ASPETTI TECNICI E NORMATIVI

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DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

EnergyMed

Università degli Studi di Napoli Federico II

Dipartimento di Ingegneria Industriale

04 QUANTO TEMPO TRASCORRIAMO ALL'INTERNO/ESTERNO ?

Mediamente un uomo trascorre il 90 per cento del suo tempo in spazi chiusi (circa 22 ore al giorno).

Ambienti poco illuminati naturalmente possono influire negativamente sulla regolazione del ritmo circadiano e quindi sui ritmi sonno-veglia, sull'umore e sulle prestazioni.

05 LUCE E RITMI CIRCADIANI

I nostri ritmi di vita sono influenzati costantemente dalla quantità e dalla qualità della luce che arriva ai nostri occhi.
Il nostro benessere dipende quindi anche da una corretta progettazione illuminotecnica.

06

RISPOSTE NON VISIVE

Emotive
aumento di

Cambiamenti di umore
Irritabilità
Ansia
Perdita di empatia
Frustrazione
Impulsività
Depressione

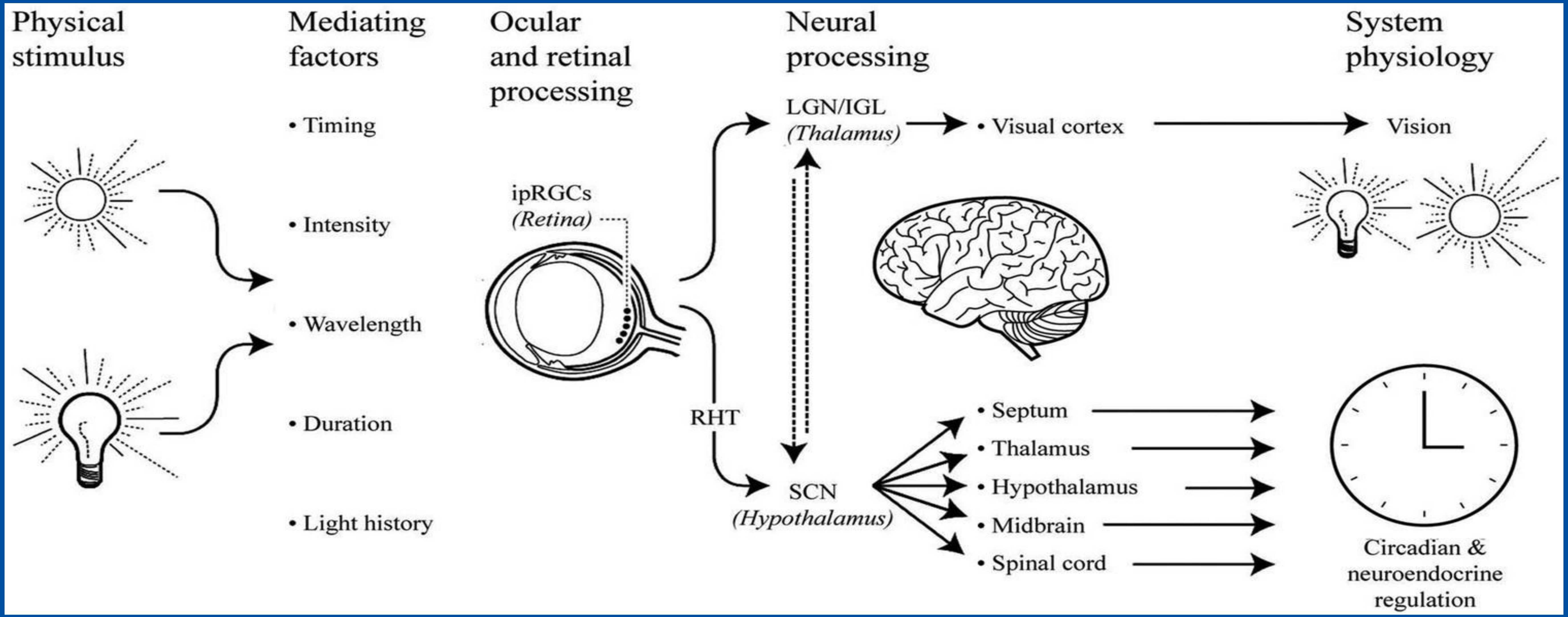
Cognitive
scompenso in

Performance
Capacità di multitasking
Memoria
Attenzione
Concentrazione
Comunicazione
Produttività

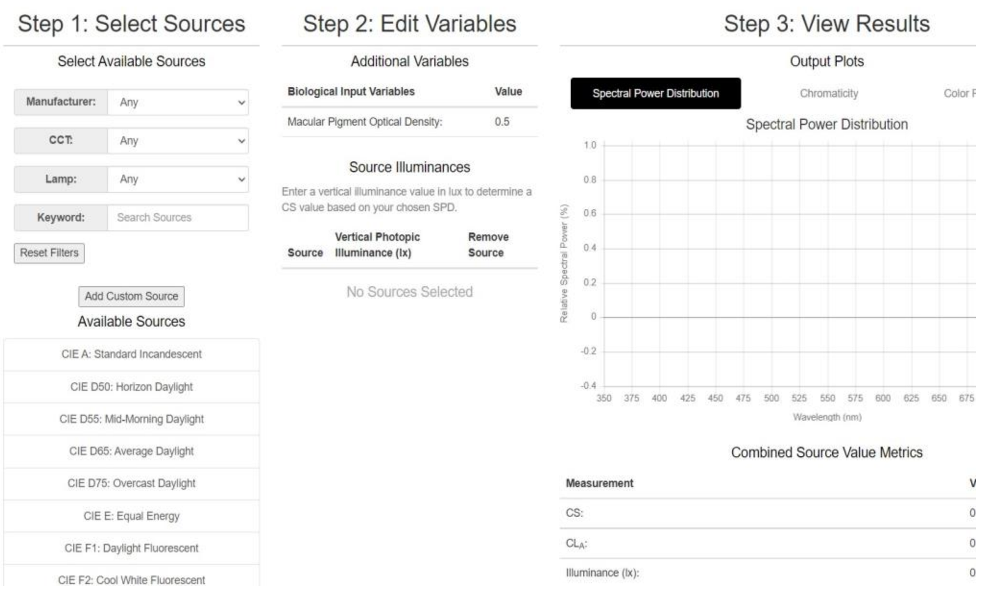
Fisiologiche
aumento del rischio di

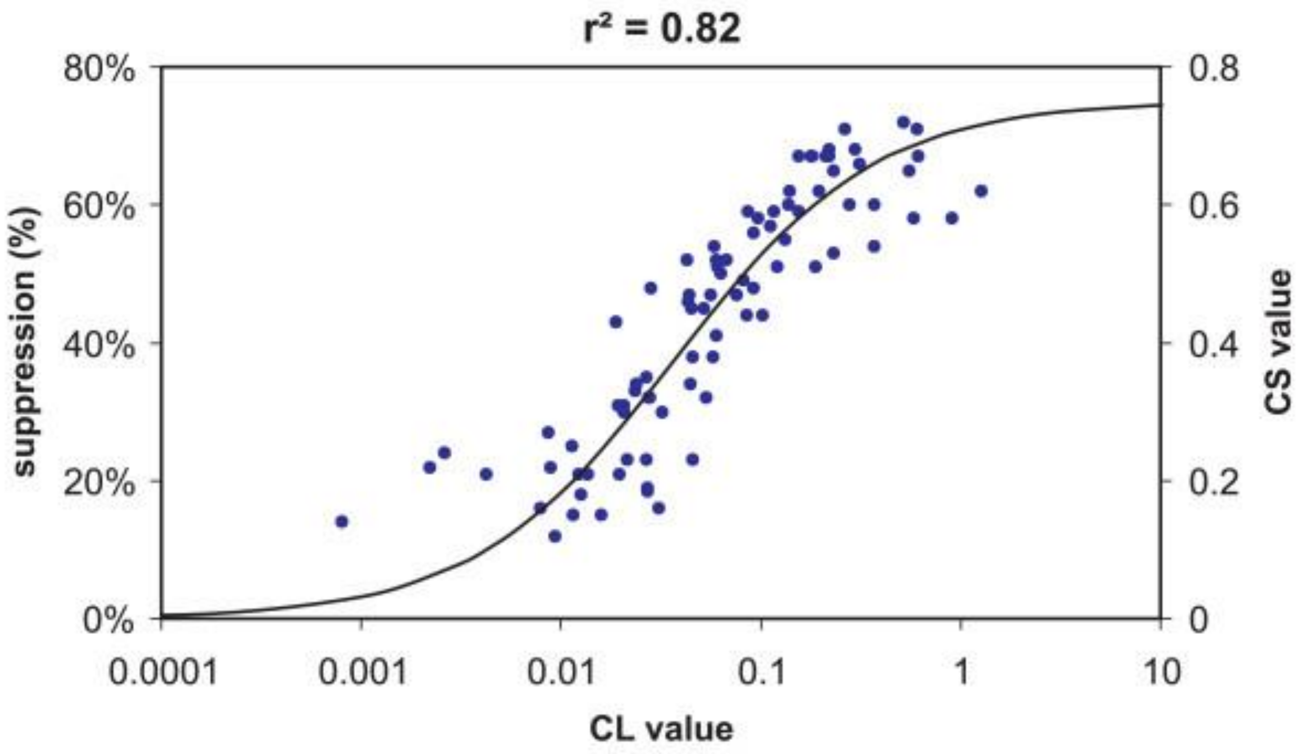
Sonnolenza diurna
Disturbi cardiovascolari
Infezioni
Cancro
Metabolismo anomalo
Diabete
Psicosi

07 REGOLAZIONE DEI RITMI CIRCADIANI



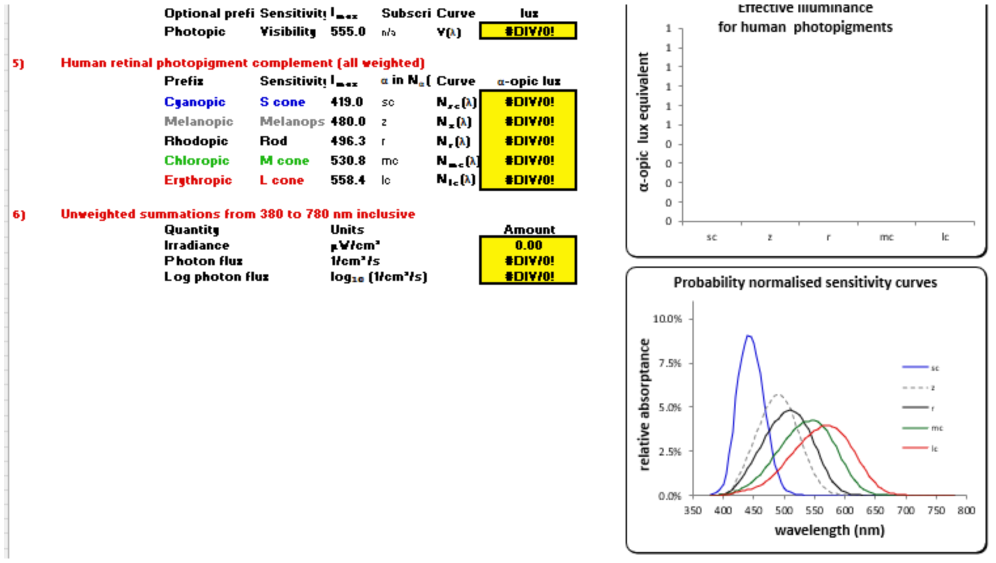
4 MODELLI DI CALCOLO

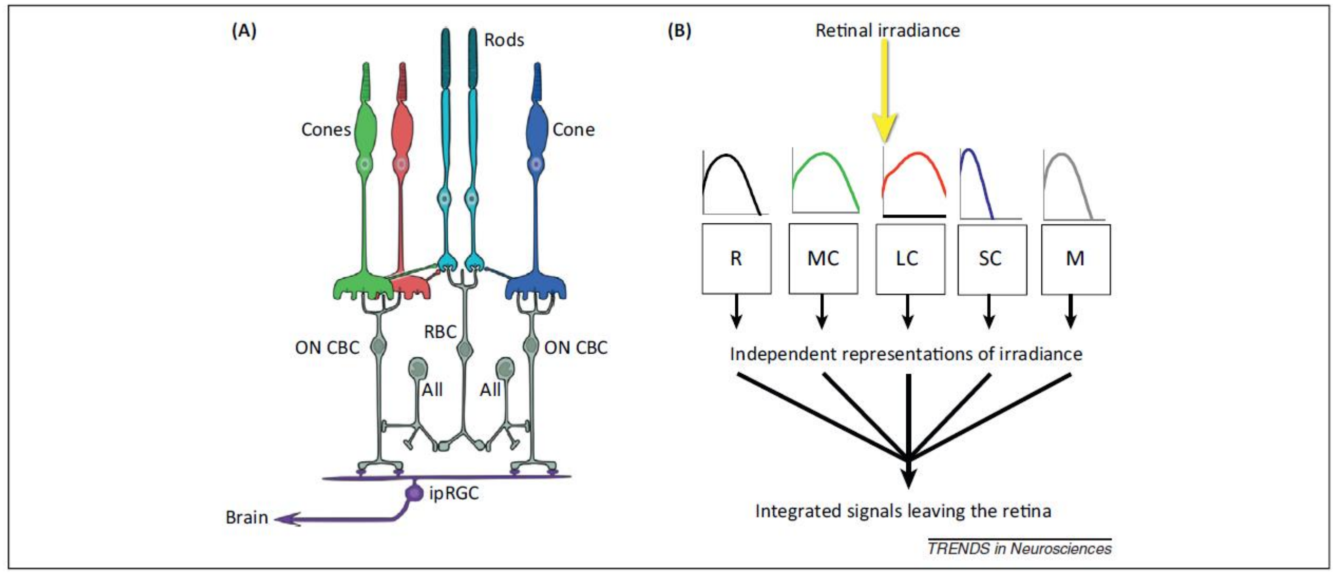




A

Model of Human Circadian Phototransduction
Rea et al

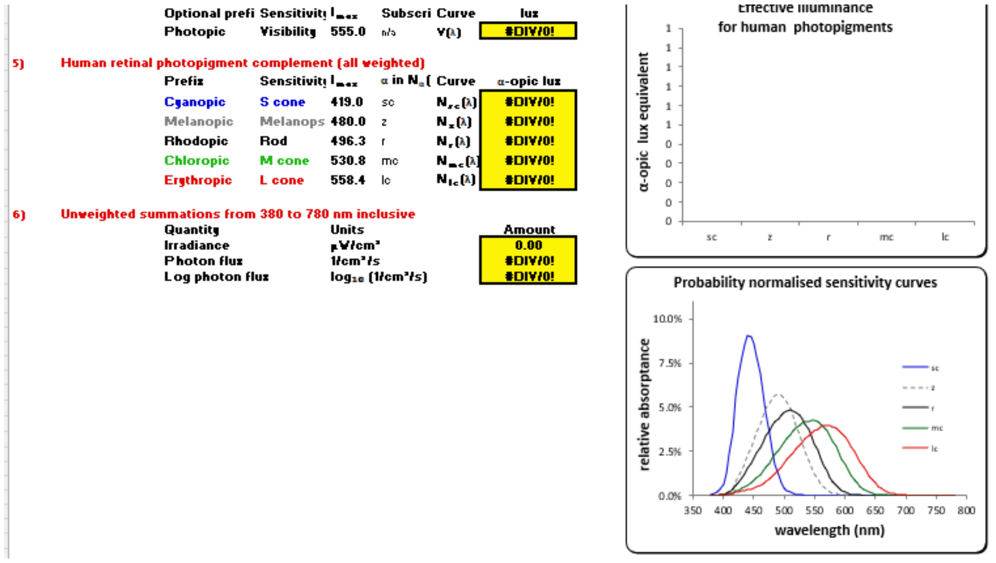




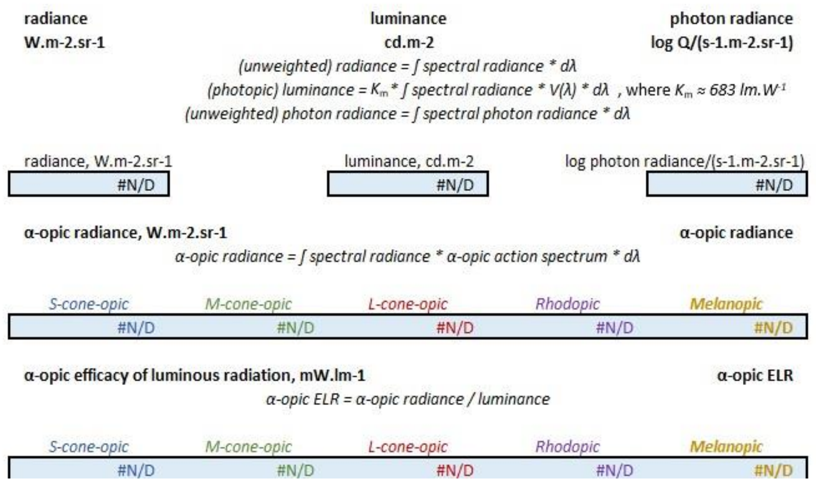
B

Toolbox Irradiance
Lucas et al

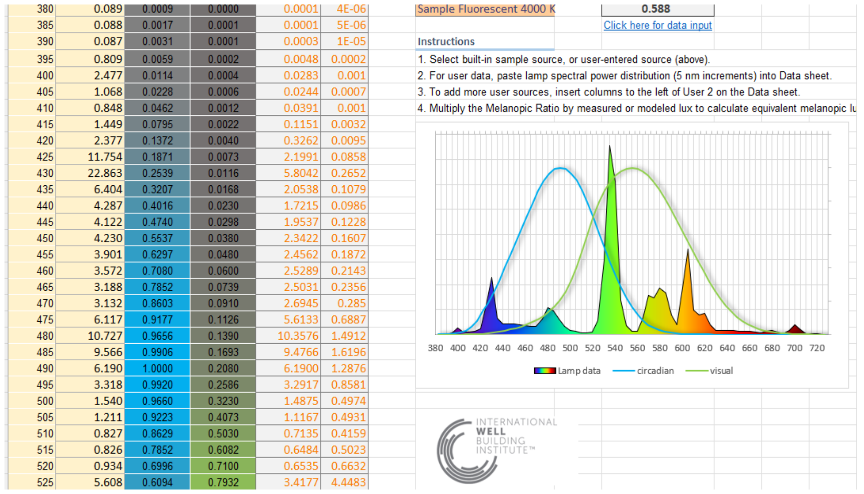
4 MODELLI DI CALCOLO



B Toolbox Irradiance
Lucas et al



C s 026 alpha-opic Toolbox
CIE



D Melanopic Ratio
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A

Model of Human Circadian Phototransduction

Rea et al.

Questo modello può essere utilizzato per calcolare l'efficacia di uno stimolo luminoso in termini di soppressione notturna di melatonina (stimolo circadiano o CS)

Il modello utilizza la distribuzione spettrale dell'irradianza di una data sorgente luminosa per calcolare la luce circadiana (CLA)

A

Model of Human Circadian Phototransduction - Rea et al.

$$CL_A = \begin{cases} 1548\left[\int Mc_\lambda E_\lambda \mathrm{d}\lambda + \left(a_{b-y}\left(\int \frac{S_\lambda}{mp_\lambda}E_\lambda \mathrm{d}\lambda - k\int \frac{V_\lambda}{mp_\lambda}E_\lambda \mathrm{d}\lambda\right) - a_{rod}\left(1 - e^{\frac{-\int V'_\lambda E_\lambda \mathrm{d}\lambda}{RodSat}}\right)\right)\right] & if \int \frac{S_\lambda}{mp_\lambda}E_\lambda \mathrm{d}\lambda - k\int \frac{V_\lambda}{mp_\lambda}E_\lambda \mathrm{d}\lambda > 0 \\ 1548\int Mc_\lambda E_\lambda \mathrm{d}\lambda & if \int \frac{S_\lambda}{mp_\lambda}E_\lambda \mathrm{d}\lambda - k\int \frac{V_\lambda}{mp_\lambda}E_\lambda \mathrm{d}\lambda \leq 0 \end{cases}$$

CL_A: circadian light. The constant, 1548, sets the normalization of CL_A so that 2856 K blackbody radiation at 1000 lux has a CL_A value of 1000.

E_λ: light source spectral irradiance distribution

Mc_λ: melanopsin (corrected for crystalline lens transmittance)

S_λ: S-cone fundamental

mp_λ: macular pigment transmittance

V_λ: photopic luminous efficiency function

V'_λ: scotopic luminous efficiency function

RodSat: half-saturation constant for bleaching rods = 6.5 W/m²

k = 0.2616

a_{b-y} = 0.700

a_{rod} = 3.300

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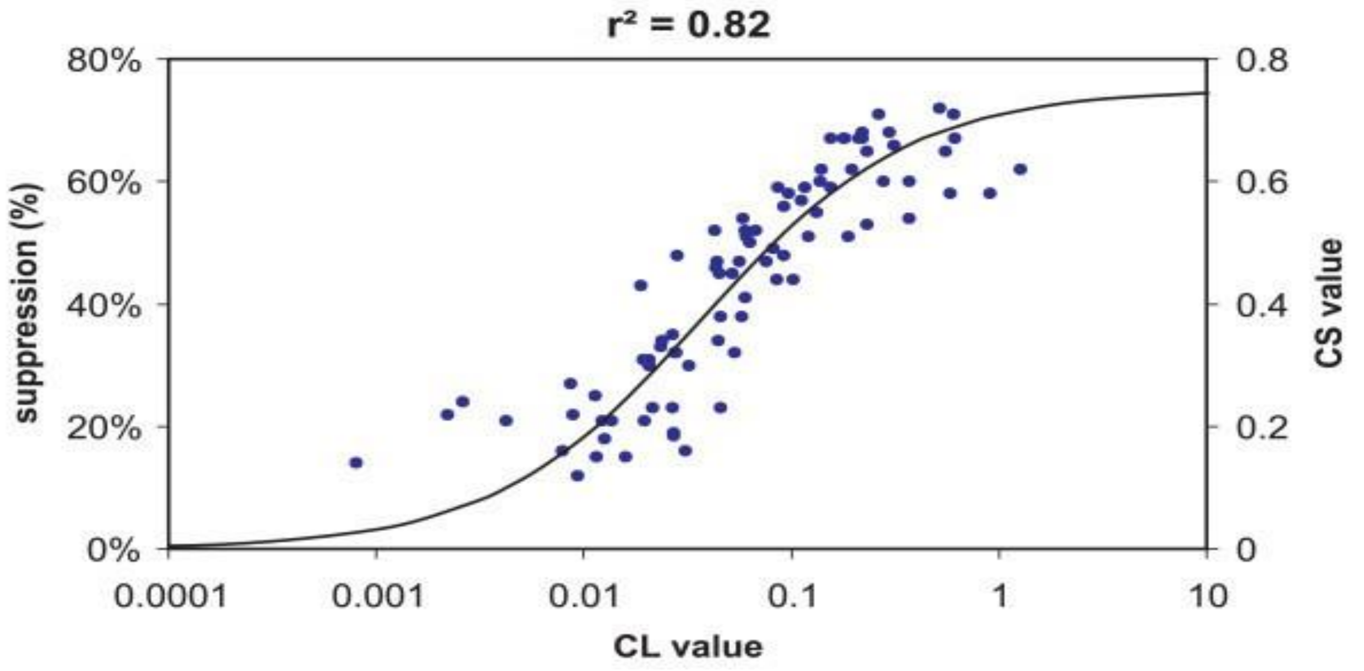
Model of Human Circadian Phototransduction - Rea et al.

$$CS = 0.7 - \frac{0.7}{1+\left(\frac{CL_A}{355.7}\right)^{1.1026}}$$

$$CL_A = \begin{cases} 1548\left[\int M_{C\lambda}E_\lambda d\lambda + \left(a_{b-y}\left(\int \frac{S_\lambda}{mp_\lambda}E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda}E_\lambda d\lambda\right) - a_{rod}\left(1 - e^{\frac{-\int V'_\lambda E_\lambda d\lambda}{RodSat}}\right)\right)\right], \\ \quad if \int \frac{S_\lambda}{mp_\lambda}E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda}E_\lambda d\lambda \geq 0 \\ 1548\int M_{C\lambda}E_\lambda d\lambda\,,\ if\ \int \frac{S_\lambda}{mp_\lambda}E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda}E_\lambda d\lambda < 0 \end{cases}$$



A

Model of Human Circadian Phototransduction - Rea et al.

Lighting Research Center | Light and Health | Circadian-Effective Light | Designing with Circadian Stimulus | Contact | Instructional Video | Help off

Step 1: Select Sources

Select Available Sources

Manufacturer:	Any
CCT:	3000
Lamp:	LED
Keyword:	Search Sources

Reset Filters

Add Custom Source

Available Sources

- LED Hybrid Blue Pump 2
- LED Hybrid Blue Pump 4
- LED Hybrid Blue Pump 5
- LED Hybrid Blue Pump 6
- LED Hybrid Violet Pump 1
- LED Phosphor Blue Pump 2
- LED Phosphor Blue Pump 4
- LED Phosphor Blue Pump 6

Step 2: Edit Variables

Additional Variables

Biological Input Variables	Value
Macular Pigment Optical Density:	0.5

Source Illuminances

Enter a vertical illuminance value in lux to determine a CS value based on your chosen SPD.

Source	Vertical Photopic Illuminance (lx)	Remove Source
LED Hybrid Blue Pump 2	285.34	🗑

- OR -

Source Circadian Stimulus

Enter a target CS value to determine the vertical illuminance needed to achieve this target based on your chosen SPD.

Circadian Stimulus (CS)

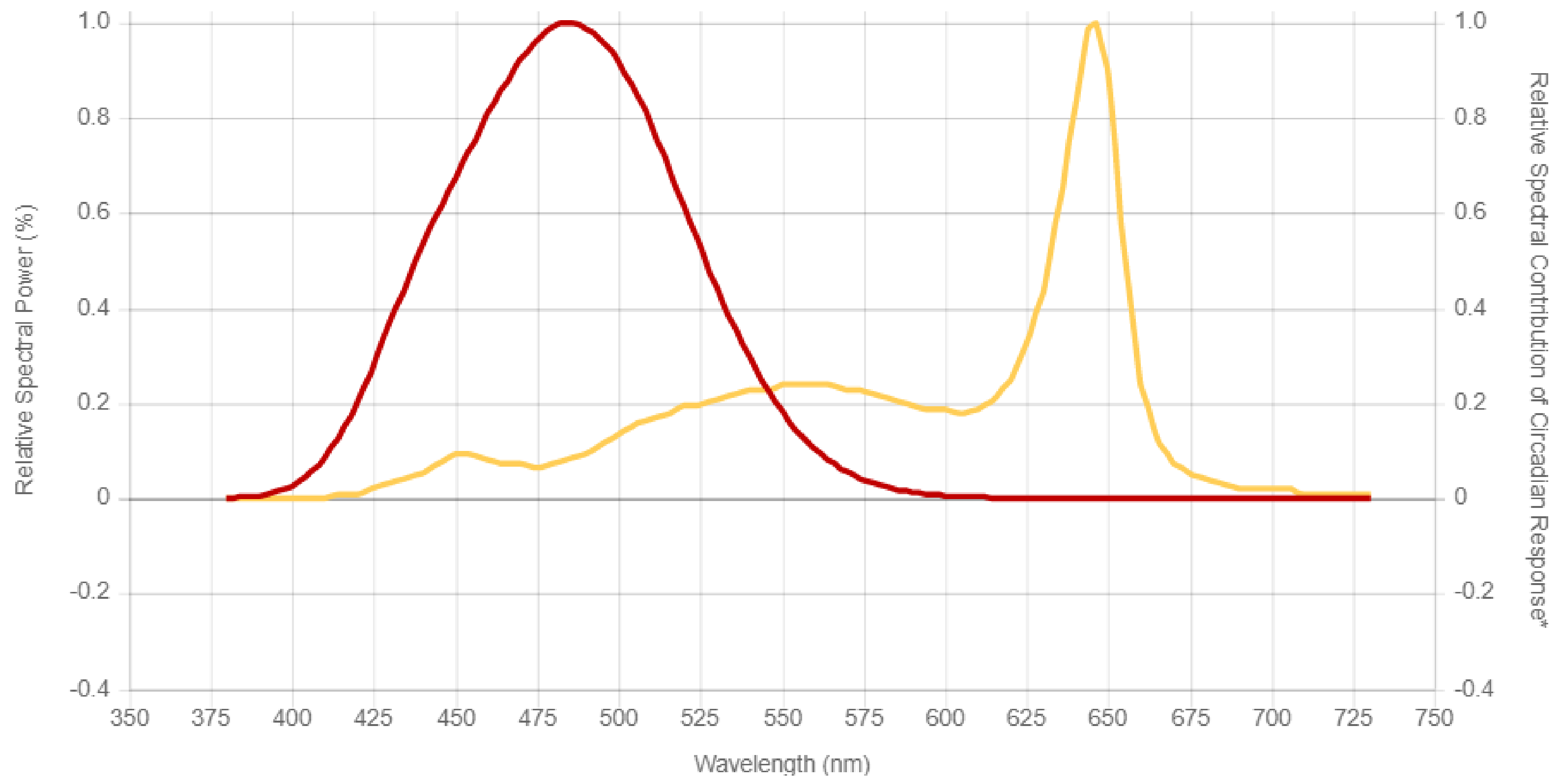
0.300

Step 3: View Results

Output Plots

Spectral Power Distribution | Chromaticity | Color Rendering Metrics

Spectral Power Distribution



Legend

- Relative Spectral Contribution of the Circadian Response*: Warm
- LED Hybrid Blue Pump 2

* For the Specified Spectral Power Distribution [Spectrum, Amount]

Information on the calculation of Circadian Light, Corrigendum

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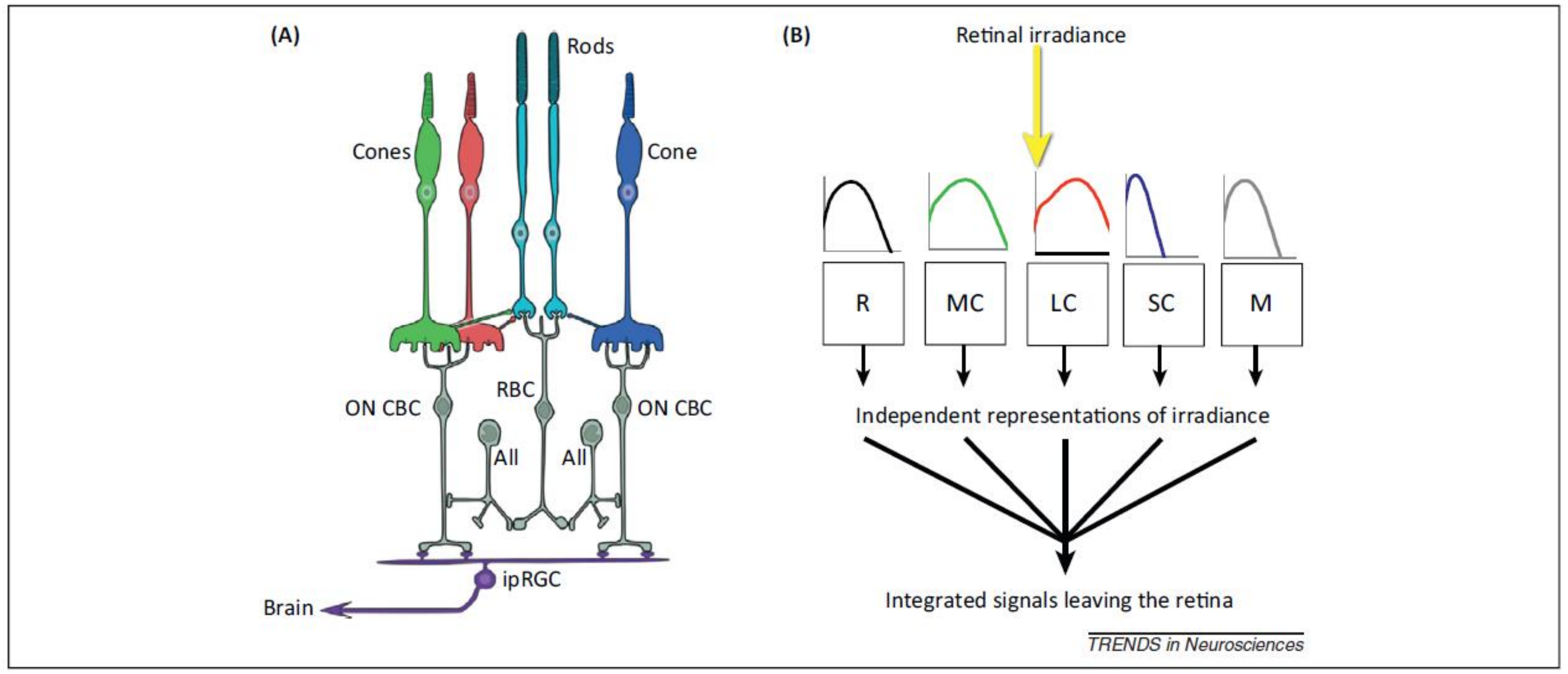
B

Irradiance Toolbox

Lucas et al.

Il modello si basa sulle risposte spettrali dei fotopigmenti nei fotorecettori (ipRGC, coni e bastoncelli), attraverso le quali è possibile calcolare i valori equivalenti di illuminamento "α-opico" per ciascuno dei 5 fotopigmenti nell'occhio umano.



B

Toolbox Irradiance - Lucas et al.

Irradiance Toolbox

Title Source 1

Chart input Pigment Melanopic

Page 1

1) **Select mode** 5nm spectral data
- i. Enter spectral power distribution in column AH
- ii. Check using the chart opposite that the data is 5nm resolution
- iii. Skip sections 2 and 3: these inputs are not applicable in this mode

2) **Details of light measurement**

Light source	A	n/a
Units	L	n/a
Amount	100.00	n/a

3) **For blackbody or narrowband sources**

Blackbody temperature	4200	n/a		nm
Narrowband peak	420	n/a		
Narrowband FWHM	42	n/a	Peak spectral irradiance	620

4) **Photopic illuminance**

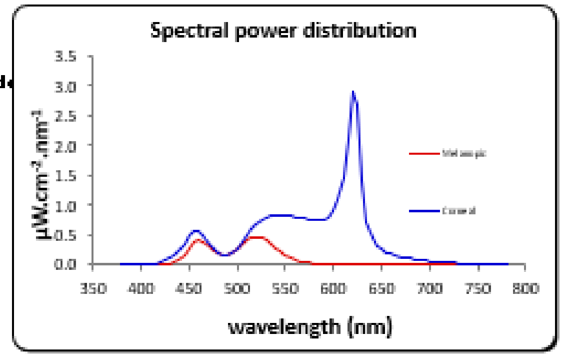
Optional pref	Sensitivity	λ_{max}	Subscript	Curve	lux
Photopic	Visibility	555.0	n/a	V(λ)	121.53

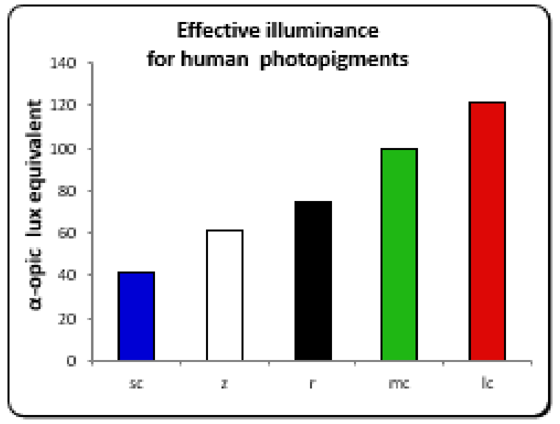
5) **Human retinal photopigment complement (all weighted)**

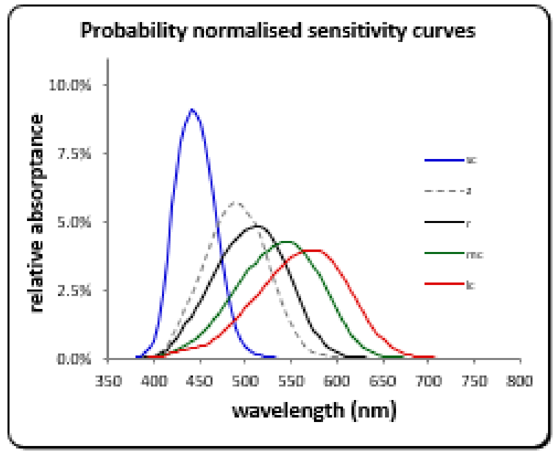
Prefix	Sensitivity	λ_{max}	α in N_α	Curve	α-opic lux
Cyanopic	S cone	419.0	sc	$N_{sc}(\lambda)$	41.71
Melanopic	Melanopsin	480.0	z	$N_z(\lambda)$	61.38
Rhodopic	Rod	496.3	r	$N_r(\lambda)$	74.65
Chloropic	M cone	530.8	mc	$N_{mc}(\lambda)$	99.16
Erythropic	L cone	558.4	lc	$N_{lc}(\lambda)$	120.80

6) **Unweighted summations from 380 to 780 nm inclusive**

Quantity	Units	Amount
Irradiance	μW/cm²	34.45
Photon flux	1/cm²/s	9.94E+13
Log photon flux	log_{10} (1/cm²/s)	14.00







Irradiance Toolbox

Title Source 1

Page 2

User defined measurement | **Spectral breakdowns** | **Spectral power distribution chart** | **Input for user defined measurements**

nm	SPD, total in μW/cm²	nm	Lux	Power	Quanta	nm	Corneal	Melanopic	nm	SPD, total in μW/cm²
380	0	380	0	0	0.00E+00	380	0	0	380	0.000000
385	0.000947	385	4.1E-07	0.00095	1.84E+09	385	0.00095	1.6E-06	385	0.000947
390	0.00443	390	3.6E-06	0.00443	8.70E+09	390	0.00443	1.4E-05	390	0.004430
395	0.00144	395	2.1E-06	0.00144	2.86E+09	395	0.00144	8.5E-06	395	0.001440
400	0.00328	400	8.9E-06	0.00328	6.60E+09	400	0.00328	3.7E-05	400	0.003280
405	0.00513	405	2.2E-05	0.00513	1.05E+10	405	0.00513	0.00012	405	0.005130
410	0.00964	410	8E-05	0.00964	1.99E+10	410	0.00964	0.00044	410	0.009640
415	0.0223	415	0.00033	0.0223	4.66E+10	415	0.0223	0.00177	415	0.022300
420	0.0447	420	0.00122	0.0447	9.45E+10	420	0.0447	0.00613	420	0.044700
425	0.0751	425	0.00374	0.0751	1.61E+11	425	0.0751	0.01405	425	0.075100
430	0.115	430	0.00911	0.115	2.49E+11	430	0.115	0.02919	430	0.115000
435	0.171	435	0.01967	0.171	3.74E+11	435	0.171	0.05484	435	0.171000
440	0.245	440	0.03849	0.245	5.43E+11	440	0.245	0.09839	440	0.245000
445	0.358	445	0.07287	0.358	8.02E+11	445	0.358	0.16969	445	0.358000
450	0.487	450	0.1264	0.487	1.10E+12	450	0.487	0.26966	450	0.487000
455	0.586	455	0.19211	0.586	1.34E+12	455	0.586	0.36898	455	0.586000
460	0.586	460	0.24014	0.586	1.36E+12	460	0.586	0.41492	460	0.586000
465	0.481	465	0.24278	0.481	1.13E+12	465	0.481	0.37769	465	0.481000
470	0.355	470	0.2206	0.355	8.40E+11	470	0.355	0.3054	470	0.355000
475	0.264	475	0.20303	0.264	6.31E+11	475	0.264	0.24228	475	0.264000
480	0.201	480	0.19085	0.201	4.86E+11	480	0.201	0.19409	480	0.201000
485	0.168	485	0.19426	0.168	4.10E+11	485	0.168	0.16642	485	0.168000
490	0.165	490	0.23443	0.165	4.07E+11	490	0.165	0.165	490	0.165000
495	0.198	495	0.34972	0.198	4.93E+11	495	0.198	0.19642	495	0.198000
500	0.27	500	0.59565	0.27	6.80E+11	500	0.27	0.26081	500	0.270000
505	0.372	505	1.03485	0.372	9.46E+11	505	0.372	0.3431	505	0.372000
510	0.481	510	1.65247	0.481	1.23E+12	510	0.481	0.41505	510	0.481000
515	0.591	515	2.45502	0.591	1.53E+12	515	0.591	0.46407	515	0.591000
520	0.676	520	3.27813	0.676	1.77E+12	520	0.676	0.47295	520	0.676000
525	0.743	525	4.02525	0.743	1.96E+12	525	0.743	0.4528	525	0.743000
530	0.783	530	4.60989	0.783	2.09E+12	530	0.783	0.40662	530	0.783000
535	0.812	535	5.07373	0.812	2.19E+12	535	0.812	0.35122	535	0.812000
540	0.821	540	5.3495	0.821	2.23E+12	540	0.821	0.28875	540	0.821000
545	0.822	545	5.50367	0.822	2.26E+12	545	0.822	0.22945	545	0.822000
550	0.819	550	5.56553	0.819	2.27E+12	550	0.819	0.17668	550	0.819000
555	0.812	555	5.54597	0.812	2.27E+12	555	0.812	0.13159	555	0.812000
560	0.801	560	5.44349	0.801	2.26E+12	560	0.801	0.09494	560	0.801000
565	0.788	565	5.26688	0.788	2.24E+12	565	0.788	0.06646	565	0.788000
570	0.773	570	5.02618	0.773	2.22E+12	570	0.773	0.04538	570	0.773000
575	0.758	575	4.73916	0.758	2.19E+12	575	0.758	0.03033	575	0.758000
580	0.745	580	4.42687	0.745	2.18E+12	580	0.745	0.02002	580	0.745000
585	0.742	585	4.1369	0.742	2.19E+12	585	0.742	0.01325	585	0.742000
590	0.75	590	3.87774	0.75	2.23E+12	590	0.75	0.00884	590	0.750000
595	0.79	595	3.74948	0.79	2.37E+12	595	0.79	0.00611	595	0.790000
600	0.89	600	3.83567	0.89	2.69E+12	600	0.89	0.00451	600	0.890000
605	1.1	605	4.25838	1.1	3.35E+12	605	1.1	0.00365	605	1.100000
610	1.47	610	5.05018	1.47	4.51E+12	610	1.47	0.0032	610	1.470000
615	2.09	615	6.29801	2.09	6.47E+12	615	2.09	0.003	615	2.090000
620	[illegible]	620	[illegible]	[illegible]	[illegible]	620	[illegible]	0.00275	620	2.900000

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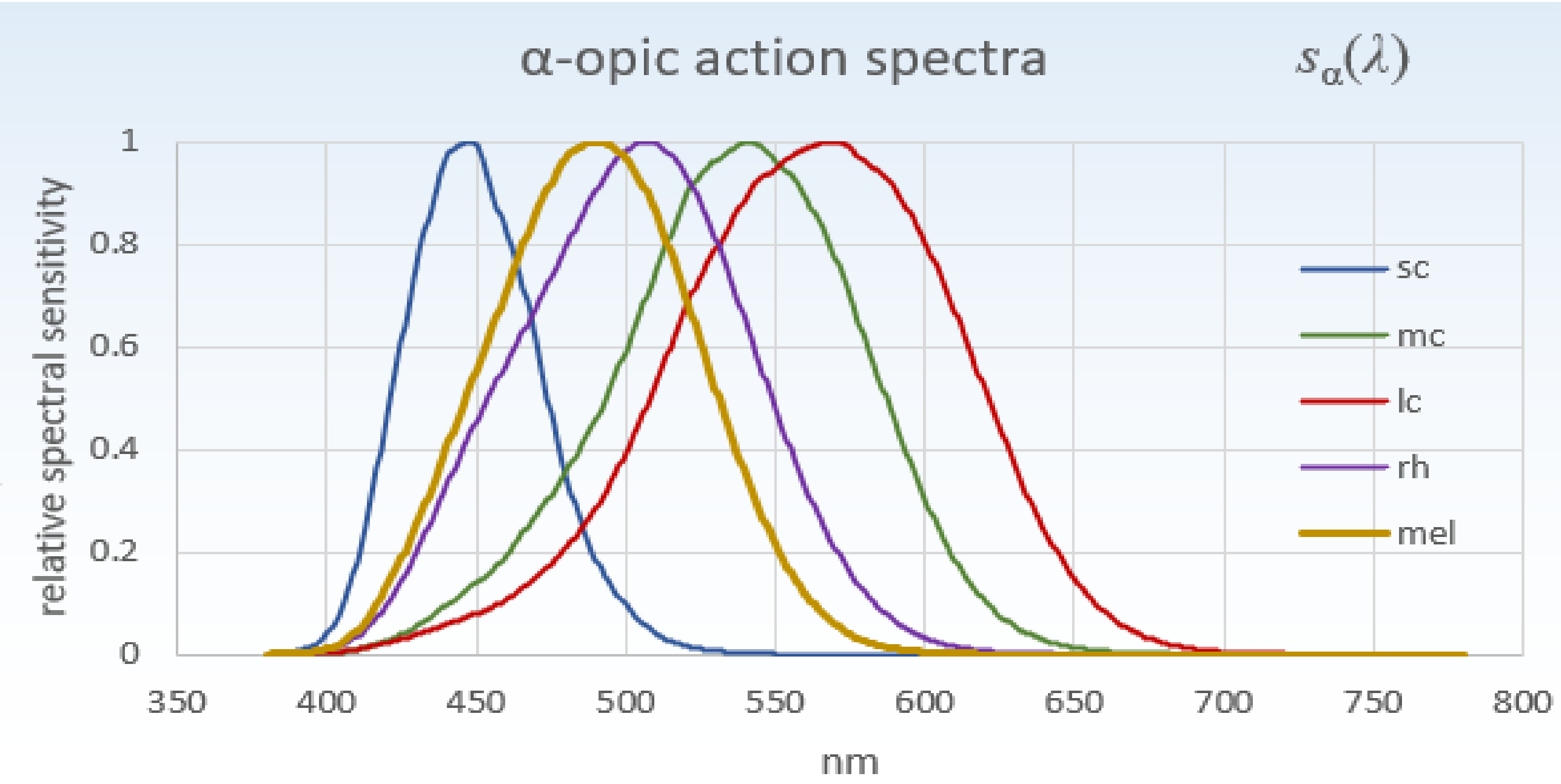
C

s 026 alpha-opic Toolbox

CIE

Il modello CIE, basato su quello di Lucas et al., consente di valutare l'EDI *Equal-energetic and D65 theoretical Illuminants*. (CIE S026:2018).



C

s 026 alpha-opic Toolbox - CIE

CIE S 026 α-opic Toolbox - v1.049a - 2020/11

Inputs sheet	Inputs = blue
Source	
1. Select source of spectral data	
Spectrum	User
2. Select measurement details	
Spectral quantity, Q	irradiance
Main SI prefix	
Area prefix	
3. Skip this step	
Clear this input	
4. Select wavelength step	
Step size, nm	5
5. Enter spectral irradiance data	
nm	W.m-2.nm-1
380	0.000000
385	0.000947
390	0.004430
395	0.001440
400	0.003280
405	0.005130
410	0.009640
415	0.022300
420	0.044700
425	0.075100
430	0.115000
435	0.171000
440	0.245000
445	0.358000
450	0.487000
455	0.586000

Instructions

CELL B5: Enter measurement name.
CELL C8: Enter "User" to enter spectrum OR select the built-in spectrum matching the conditions of your measurement value.
CELLS C11-C13: Enter the type of quantity and unit prefixes for your data.
If you selected "User" in CELL C8:
Clear CELL C17.
CELL C20: Enter wavelength step for your data (≤ 5 nm).
CELLS C24:C424: Enter spectral data to match the units and wavelength step.
If you did not select "User" in CELL C8:
CELL C17: Enter the measurement value to match the units.
Clear CELLS C24:C424.

Error messages

No errors detected.

Selected spectral quantity is permitted.

Selected prefixes are permitted.

Results based on spectral data provided.

Details of built in spectra (CIE 015:2018)

A: Range 380 nm to 780 nm, step 1 nm
D65: Range 380 nm to 780 nm, step 1 nm
E: Range 380 nm to 780 nm, step 1 nm
FL11: Range 380 nm to 780 nm, step 1 nm
LED-B3: Range 380 nm to 780 nm, step 1 nm

α-opic efficacy of luminous radiation, mW.lm-1 — **α-opic ELR**

α-opic ELR = α-opic irradiance / illuminance

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
0.2789	1.1510	1.6566	0.7897	0.6067

α-opic equivalent daylight (D65) illuminance, lx — **α-opic EDI**

α-opic EDI = α-opic irradiance / α-opic ELR for daylight (D65)

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
20735.44	48044.50	61798.40	33101.97	27799.90

log α-opic photon irradiance, log Q/(s-1.m-2), where — **α-opic photon irradiance**

*α-opic photon irradiance = ∫ spectral photon irradiance * photon system α-opic action spectrum * dλ*

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
19.582	20.280	20.458	20.087	19.958

α-opic photon irradiance in standard notation — photon irradiance, s-1.m-2

e.g. 9.078E+19 = 10^19.958, with rounding to 3 decimal places — 5.031E+20

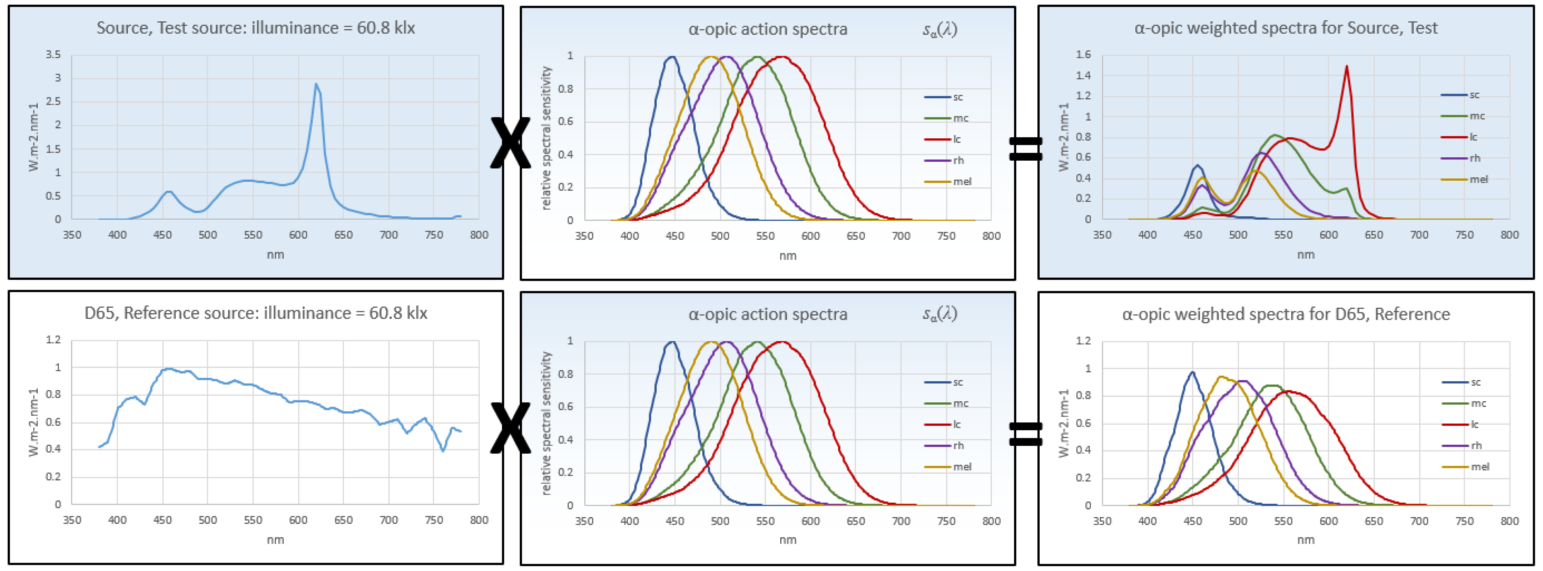
α-opic photon irradiance, s-1.m-2

S-cone-opic	M-cone-opic	L-cone-opic	Rhodopic	Melanopic
3.818E+19	1.904E+20	2.873E+20	1.222E+20	9.078E+19

CIE S 026 α-opic Toolbox - v1.049a - 2020/11

Charts

Please note the α-opic Toolbox is not part of CIE S 026. See Disclaimer sheet.



The input data is called the Test source. The default CIE S 026 Reference source is daylight (D65); Lucas et al., 2014 uses equi-energy (E).
The units used on the y-axis depend on the prefixes selected in Inputs cells C12 and C13. The units used in the chart titles depend on the prefixes selected in Advanced Outputs cells H10 and H11.

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DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

D

Melanopic Ratio

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Il metodo di valutazione degli effetti circadiani della luce proposto dallo standard WELL, basato sul modello sviluppato da Lucas et al. Consente di calcolare l’illuminamento melanopico equivalente sulla base della distribuzione spettrale calcolata della luce all’occhio.
Sulla base di questo si calcola il Melanopic Ratio.

D Melanopic Ratio - International WELL Building Institute

λ (nm	Lamp da	circadia	visual	lamp*c	lamp
380	0.000	0.0009	0.0000	0.0000	0
385	0.001	0.0017	0.0001	0.0000	6E-08
390	0.004	0.0031	0.0001	0.0000	5E-07
395	0.001	0.0059	0.0002	0.0000	3E-07
400	0.003	0.0114	0.0004	0.0000	1E-06
405	0.005	0.0228	0.0006	0.0001	3E-06
410	0.010	0.0462	0.0012	0.0004	1E-05
415	0.022	0.0795	0.0022	0.0018	5E-05
420	0.045	0.1372	0.0040	0.0061	0.0002
425	0.075	0.1871	0.0073	0.0141	0.0005
430	0.115	0.2539	0.0116	0.0292	0.0013
435	0.171	0.3207	0.0168	0.0548	0.0029
440	0.245	0.4016	0.0230	0.0984	0.0056
445	0.358	0.4740	0.0298	0.1697	0.0107
450	0.487	0.5537	0.0380	0.2697	0.0185
455	0.586	0.6297	0.0480	0.3690	0.0281
460	0.586	0.7080	0.0600	0.4149	0.0352
465	0.481	0.7852	0.0739	0.3777	0.0355
470	0.355	0.8603	0.0910	0.3054	0.0323
475	0.264	0.9177	0.1126	0.2423	0.0297
480	0.201	0.9656	0.1390	0.1941	0.0279
485	0.168	0.9906	0.1693	0.1664	0.0284
490	0.165	1.0000	0.2080	0.1650	0.0343
495	0.198	0.9920	0.2586	0.1964	0.0512
500	0.270	0.9660	0.3230	0.2608	0.0872
505	0.372	0.9223	0.4073	0.3431	0.1515
510	0.481	0.8629	0.5030	0.4150	0.2419
515	0.591	0.7852	0.6082	0.4641	0.3594
520	0.676	0.6996	0.7100	0.4729	0.48
525	0.743	0.6094	0.7932	0.4528	0.5893
530	0.783	0.5193	0.8620	0.4066	0.6749
535	0.812	0.4325	0.9149	0.3512	0.7429

Source	Melanopic Ratio
User 2	0.505

Click here for data input

Instructions

1. Select built-in sample source, or user-entered source (above).
2. For user data, paste lamp spectral power distribution (5 nm increments) into Data sheet.
3. To add more user sources, insert columns to the left of User 2 on the Data sheet.
4. Multiply the Melanopic Ratio by measured or modeled lux to calculate equivalent melano

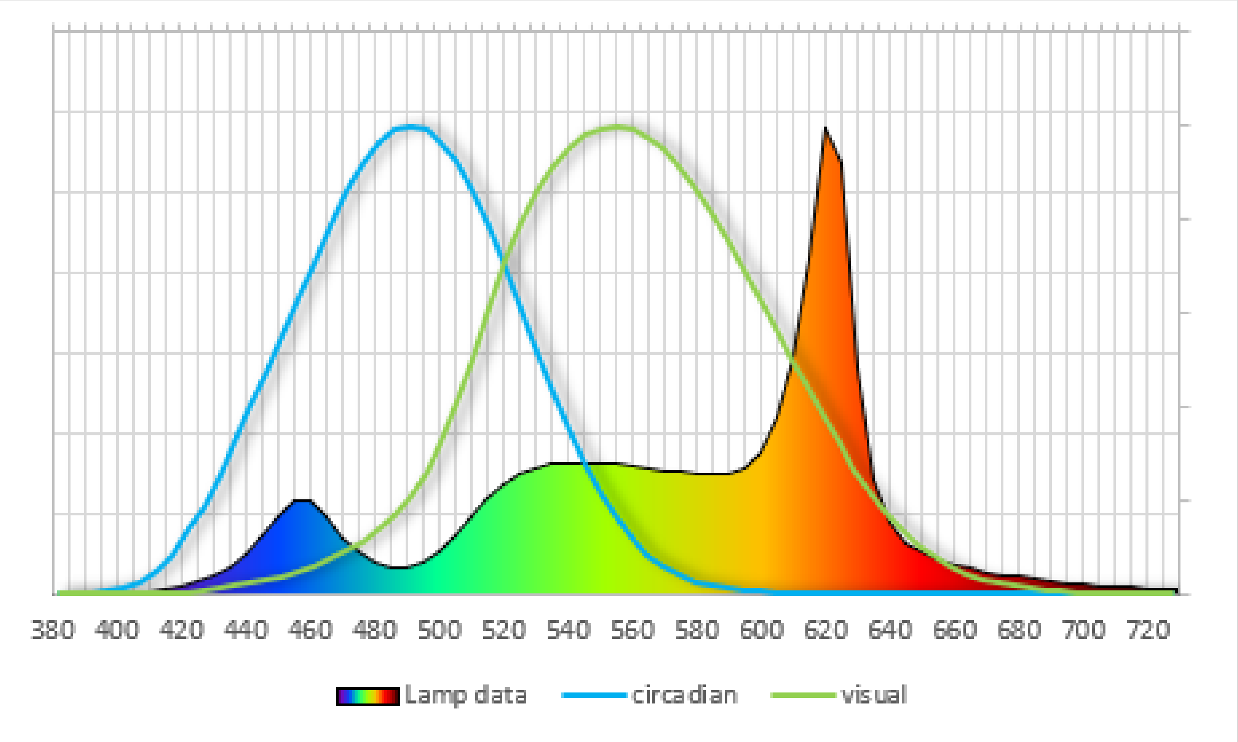

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TABELLA DI RIEPILOGO MODELLI

Modello	Model of Human Circadian Phototransduction	Toolbox Irradiance	s 026 alpha-opic Toolbox	Melanopic Ratio
INPUT	Irradianza spettrale di una data sorgente luminosa all’occhio	Irradianza spettrale di una data sorgente luminosa all’occhio	Irradianza spettrale di una data sorgente luminosa all’occhio	Irradianza spettrale di una data sorgente luminosa all’occhio
OUTPUT	CS - CLa	i valori equivalenti di illuminamento "α- opico" per ciascuno dei 5 fotopigmenti nell'occhio umano	EDI melanopic equivalent diurnal illuminance o ED65	Melanopic Ratio

Un modello utile dovrebbe essere minimamente complesso per tenere conto di un insieme esistente di dati e al massimo specifico su cosa significano i suoi parametri in termini fisiologici. Non dovrebbe puntare alla completezza.
L'essenza dell'utilità di un modello sta nell'essere una semplificazione della natura, piuttosto che nell'avvicinarsi alla complessità della natura stessa.

-Daan e Beersma

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