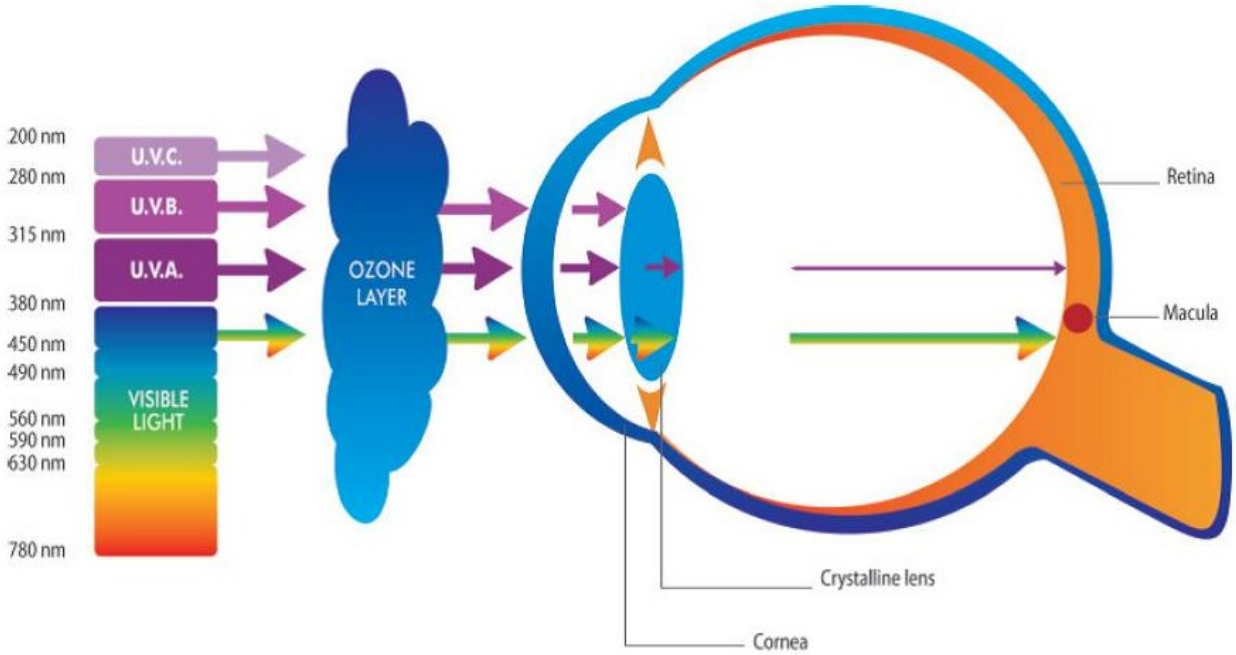


Photochromic contact lenses: Optical analysis and visual effects of their transition dynamics

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The importance of light filtering



Excessive exposure to UV light can induce:

- Pinguecola, Pterygium, and other conjunctival diseases
- photokeratitis
- cataracts
- solar retinopathy

Short-wavelength visible radiation (blue light):

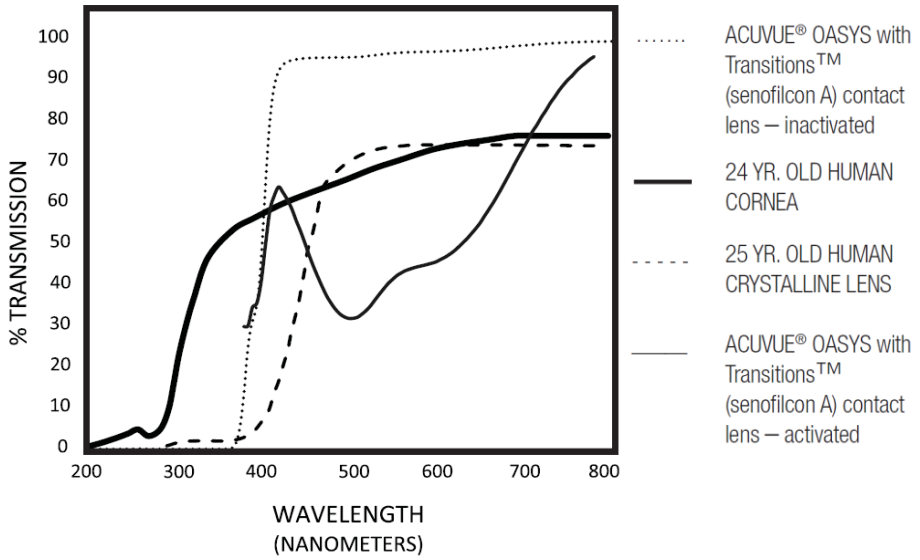
- can interfere with sleep-wake circadian cycle (melanopsin production at 480 nm)
- promotes age-related macular degeneracy (AMD)
- solar retinopathy

Additional light filtering is recommended for the eye safety!

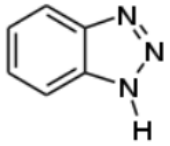
Photochromic contact lenses (J&J)

ACUVUE® OASYS with Transitions™

Spherical contact lens made of silicone hydrogel material (senofilcon A) containing an internal wetting agent, and different UV-absorbing monomers:

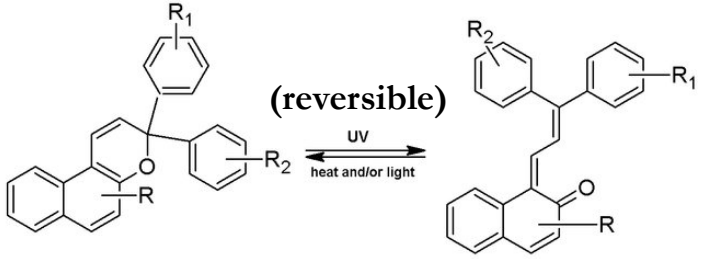


Benzotriazole monomer (UV absorbing)



To less than 1% in the UVB (280 nm to 315 nm) and less than 10% in the UVA range (316 nm to 380 nm)

naphthopyran monomer (photochromic additive)



closed form: it adsorbs UV light

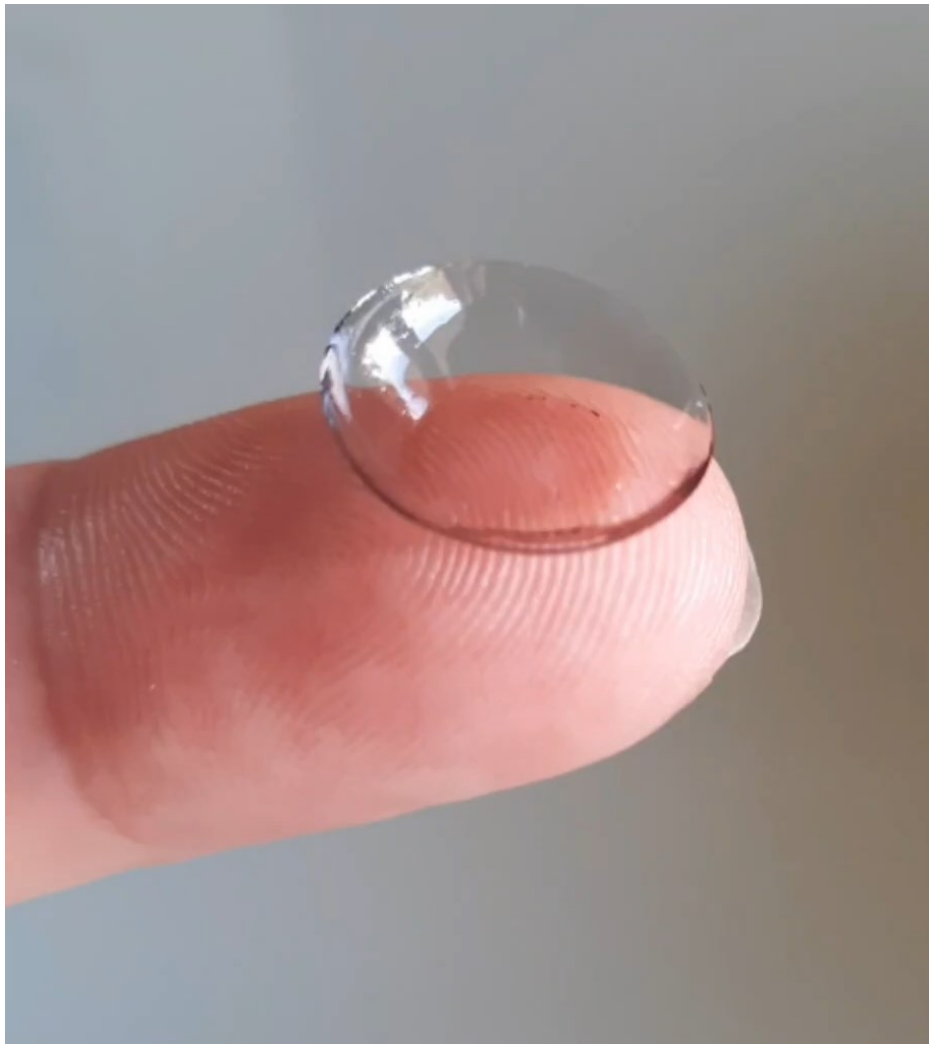
open form: it adsorbs UV & visible light

Photochromic contact lenses (J&J)

Contact Lenses That Adjust to Light

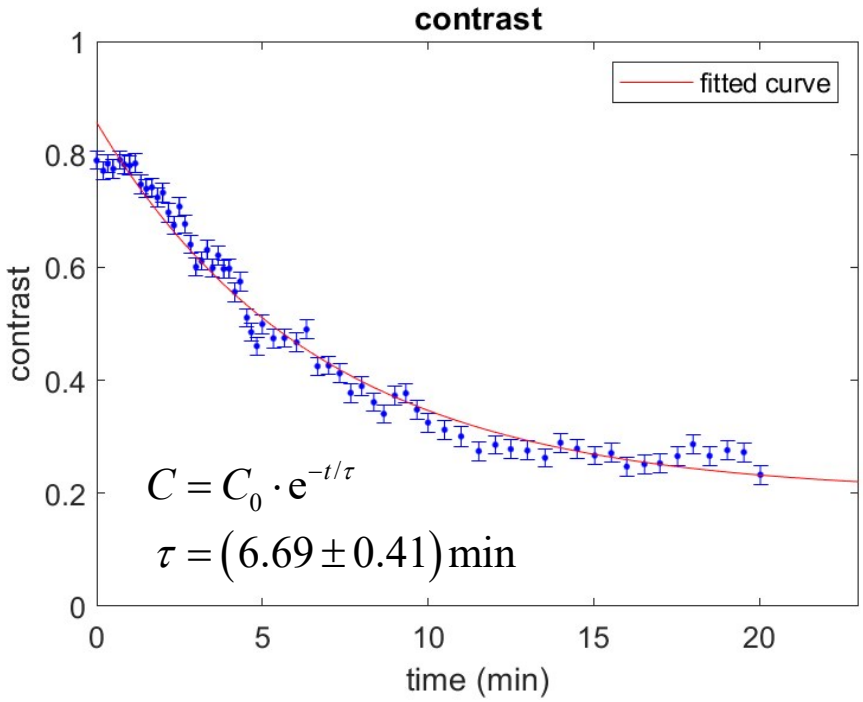
Acuvue Oasys with Transitions





(de)activation





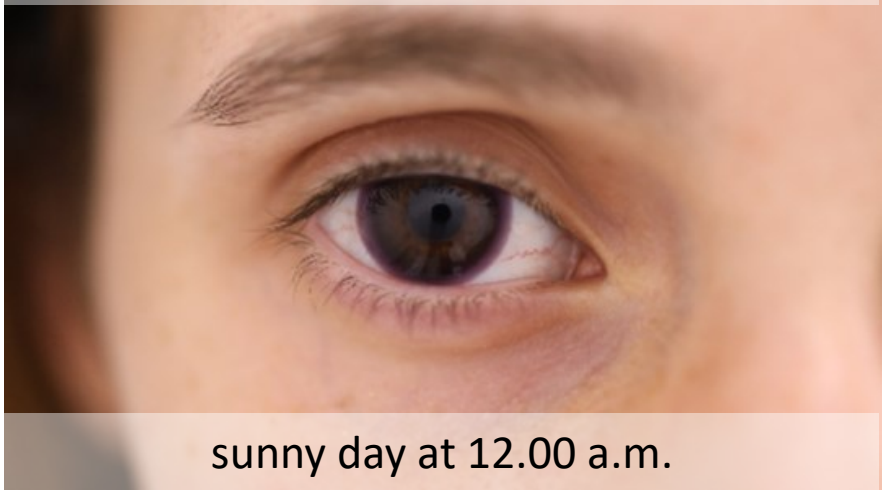
- When no longer exposed to UV light, the lens deactivates with a characteristic time around 7 min
- The activation degree depends on the UV radiation level (indoor/outdoor, sunny/cloudy, period of the year, latitude, altitude, temperature, etc.)

(de)activation

maximum activation (artificial)

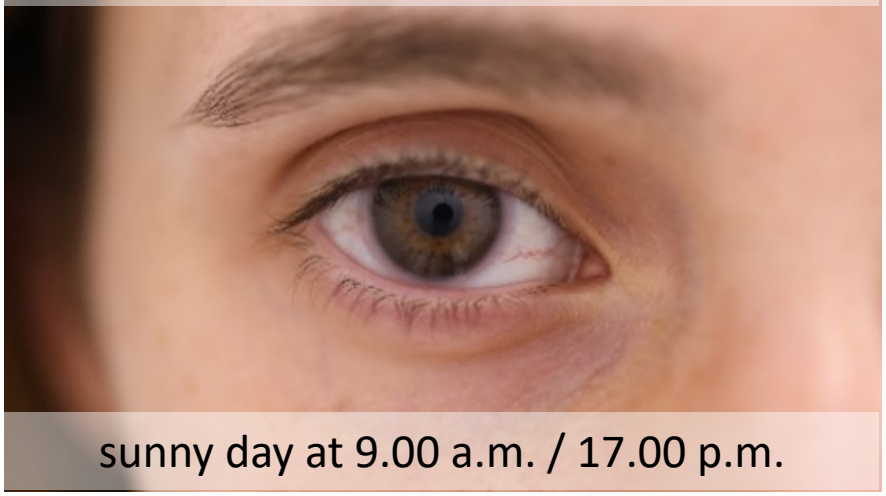


maximum activation (realistic)



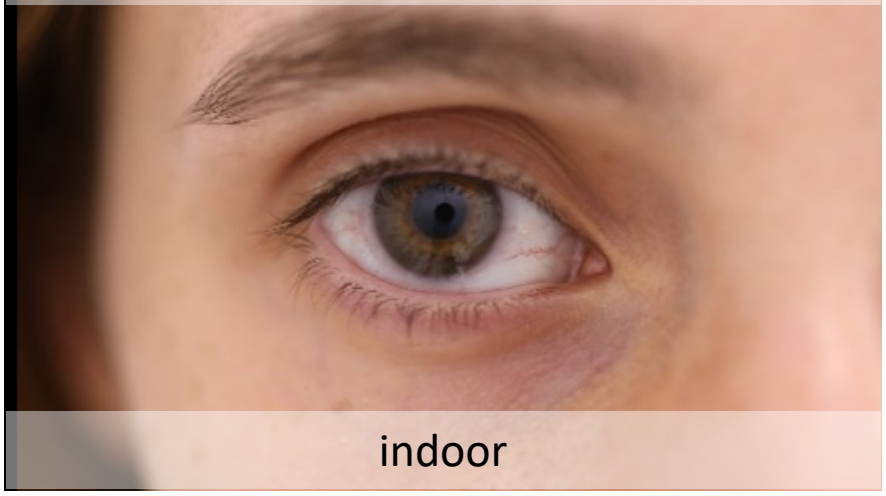
sunny day at 12.00 a.m.

intermediate activation (realistic)



sunny day at 9.00 a.m. / 17.00 p.m.

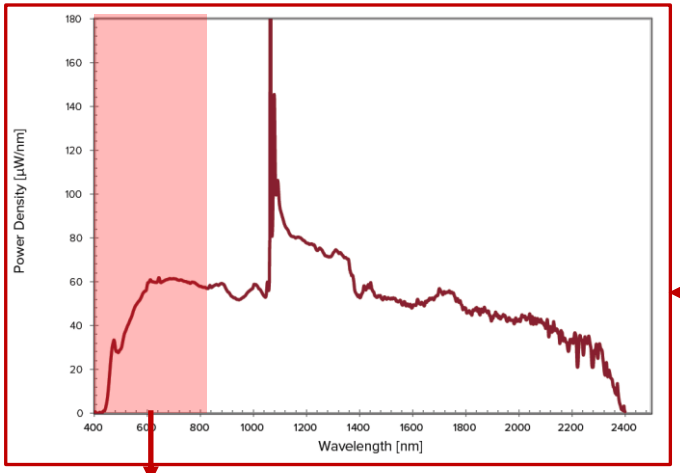
very low activation

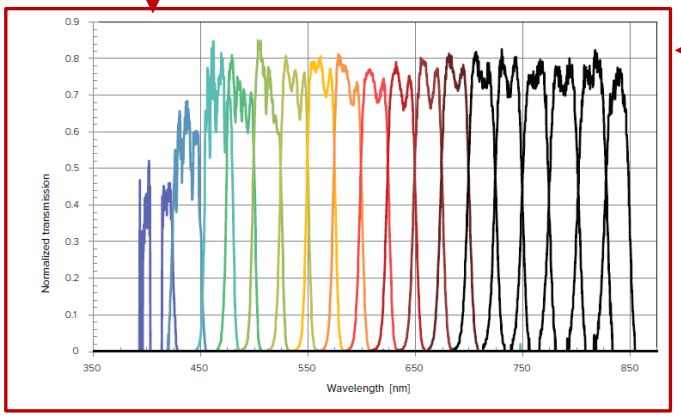


indoor

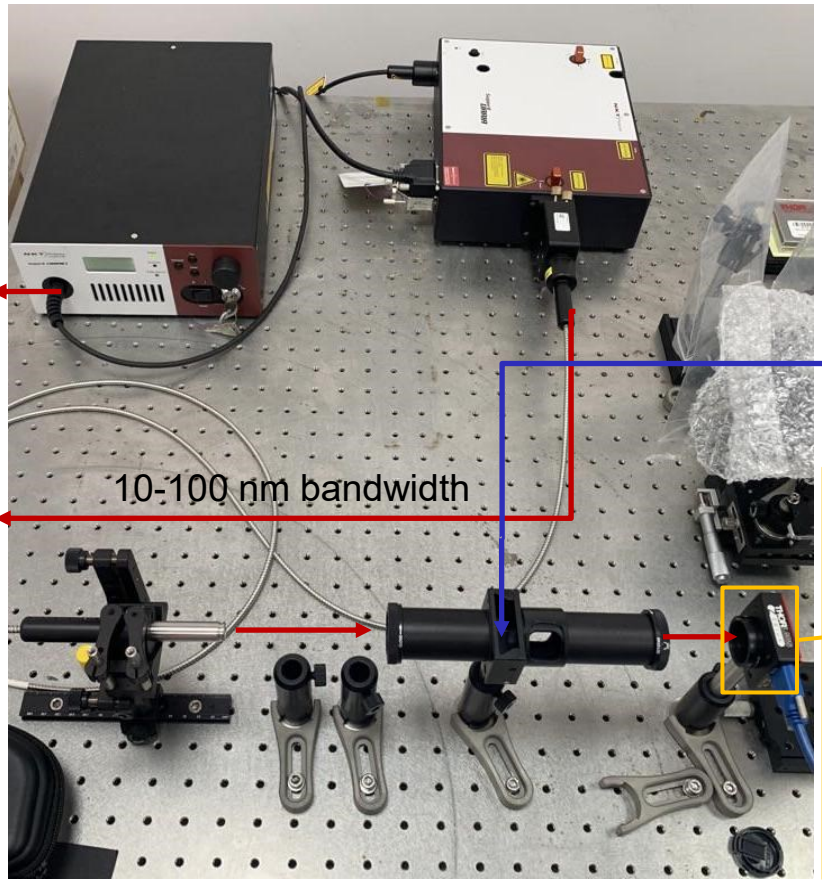
The experimental setup

Laser supercontinuum
SuperK Compact (NKT Photonics)





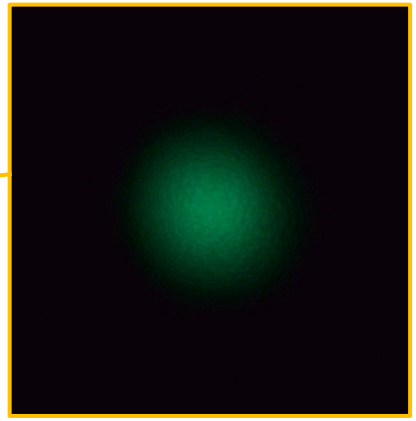
Monochromator 400-840 nm
SuperK VARIA (NKT Photonics)



optical setup assembled on an optical table in the lab

Lens holder

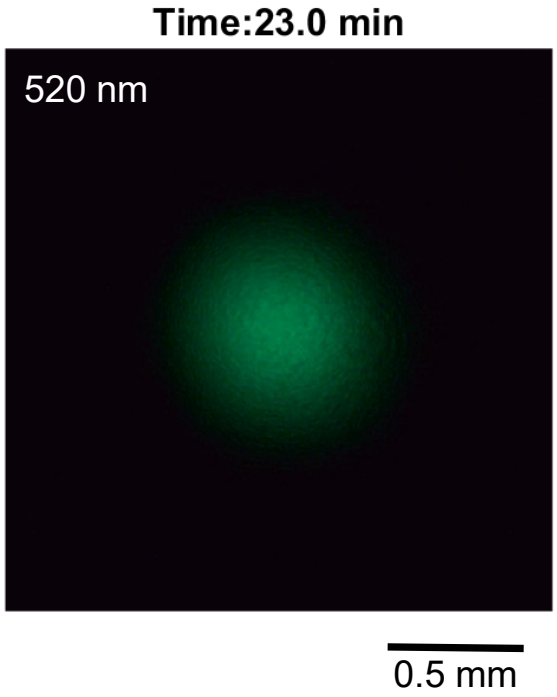


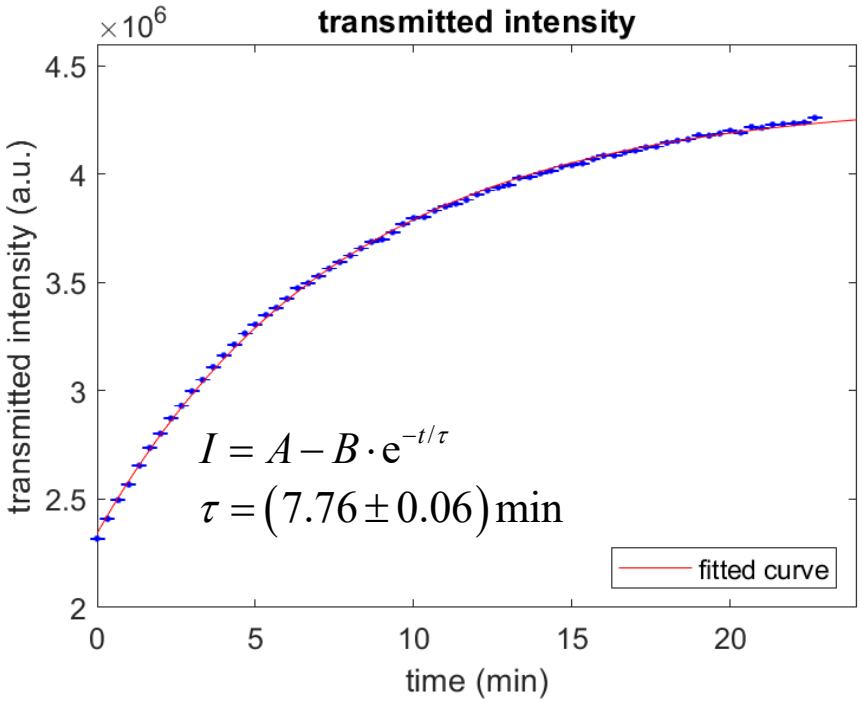


Zelux CMOS camera
1080 x 1440 pixels
3.45 um,10 bit

Deactivation analysis

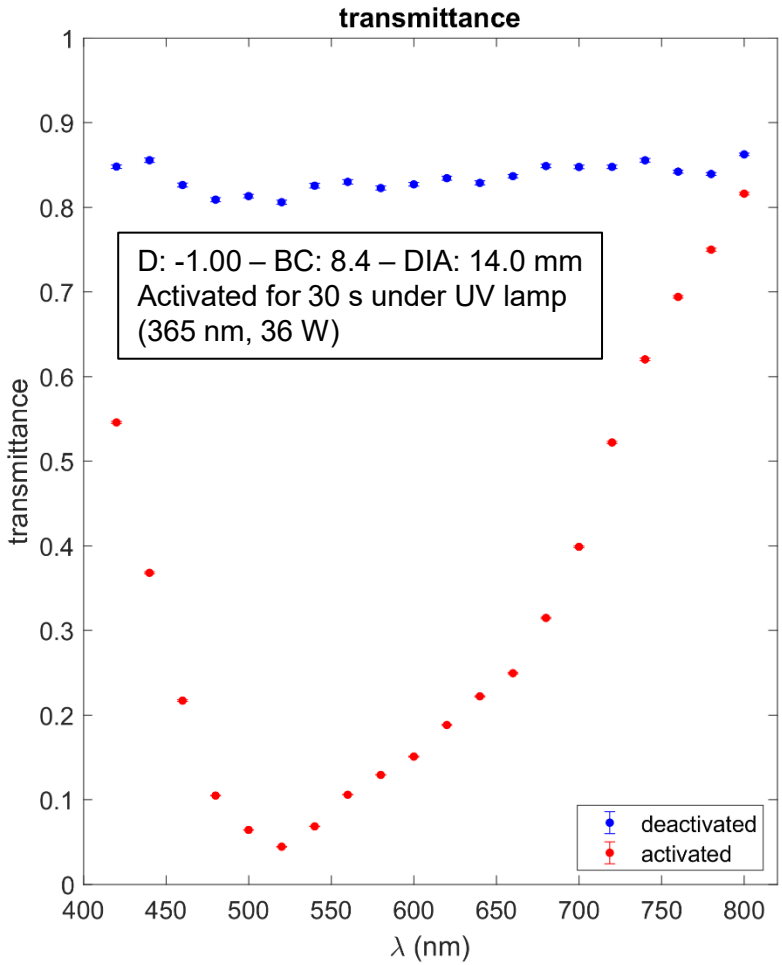
Deactivation analysis in the range 420-800 nm, step 20 nm (20 wavelengths)
Activated by a UV lamp (36 W, 365 nm, 30 s).70 acquisitions for each wavelength, step 20 s

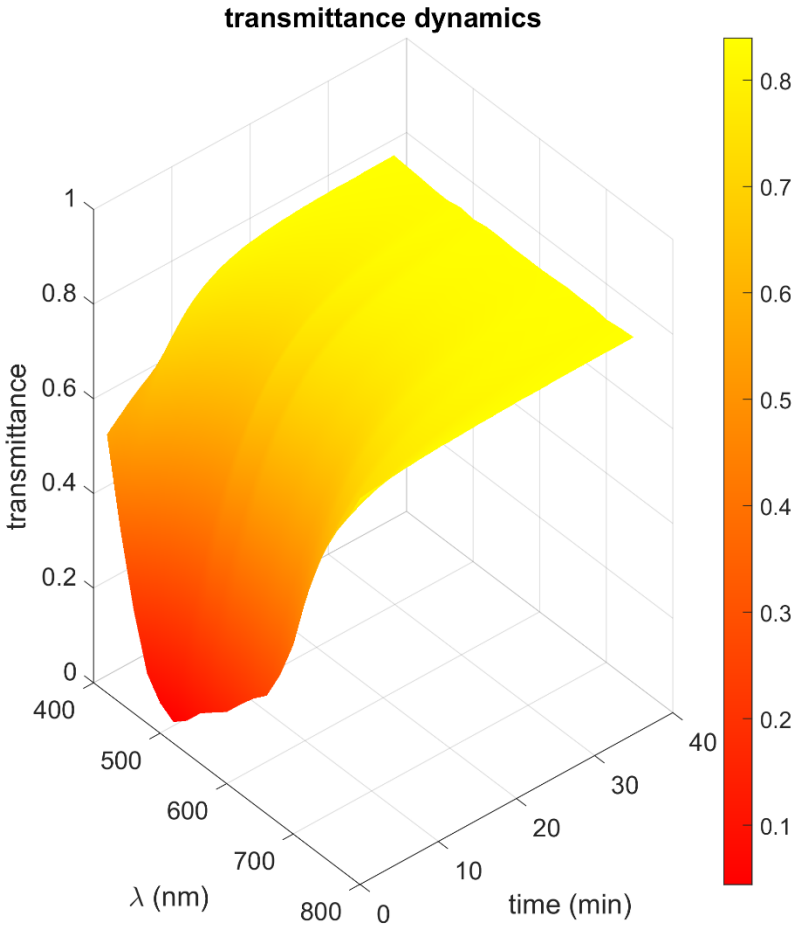




Once activated and no longer exposed to UV light, the lens deactivates, and the transmitted intensity increases with an average characteristic time around (7.17 ± 0.02) min

Transmittance analysis and dynamics

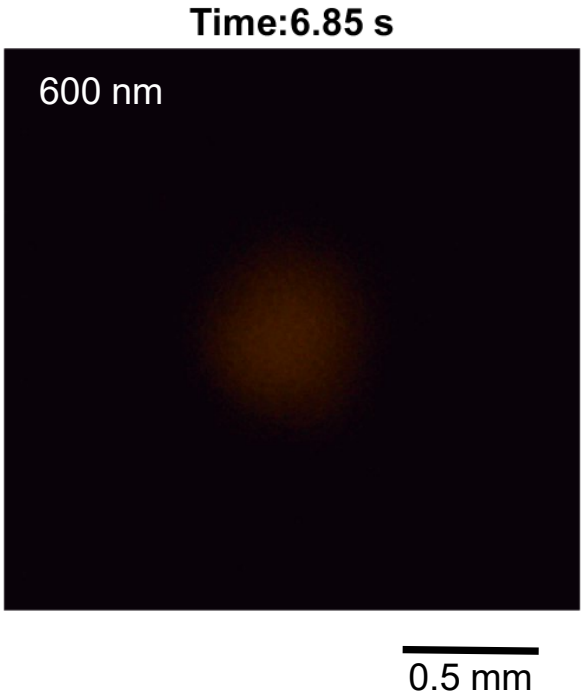


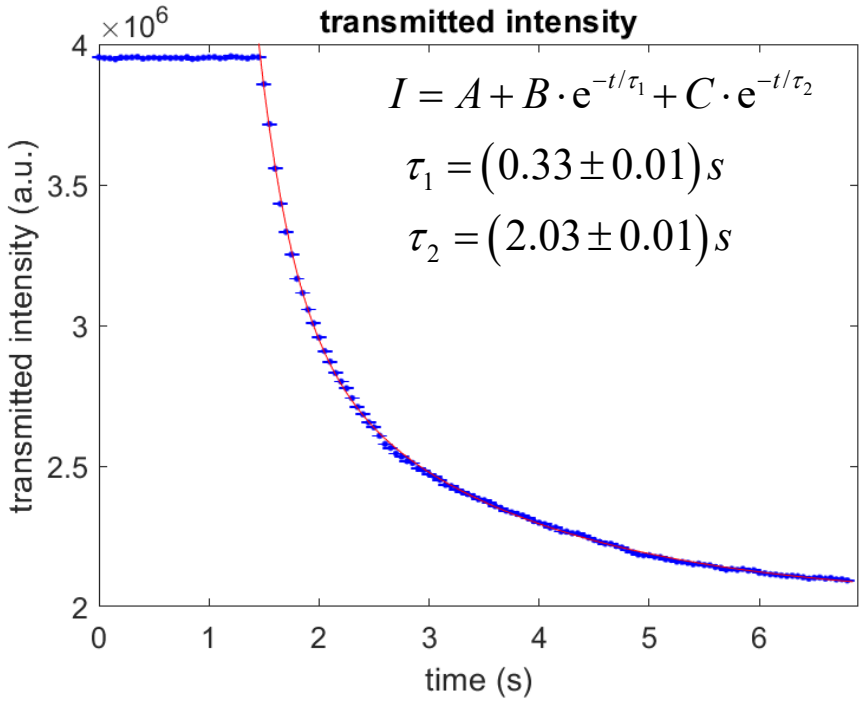


Once activated and no longer exposed to UV light, the lens deactivates, and the transmitted intensity increases with an average characteristic time around (7.17 ± 0.02) min

Activation analysis

Activation analysis in the range 420-800 nm, step 20 nm (20 wavelengths)
Activated by a UV pen (405 nm, 10 s, 1 mW). Acquisition step 10 ms



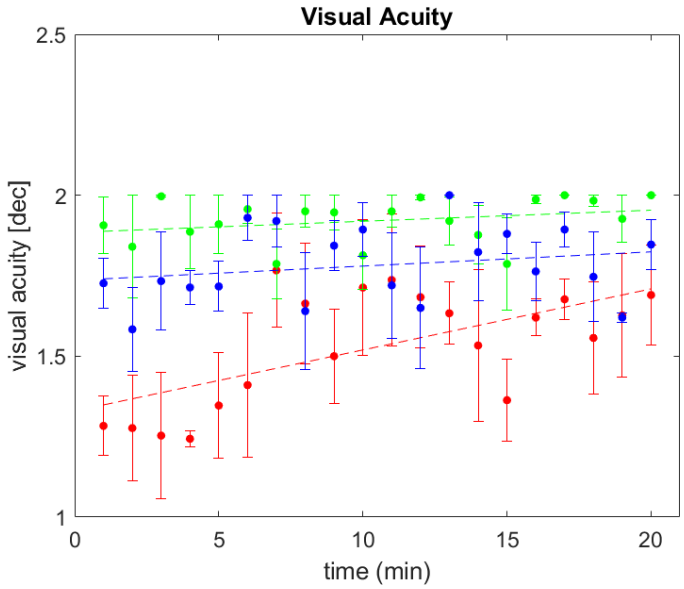


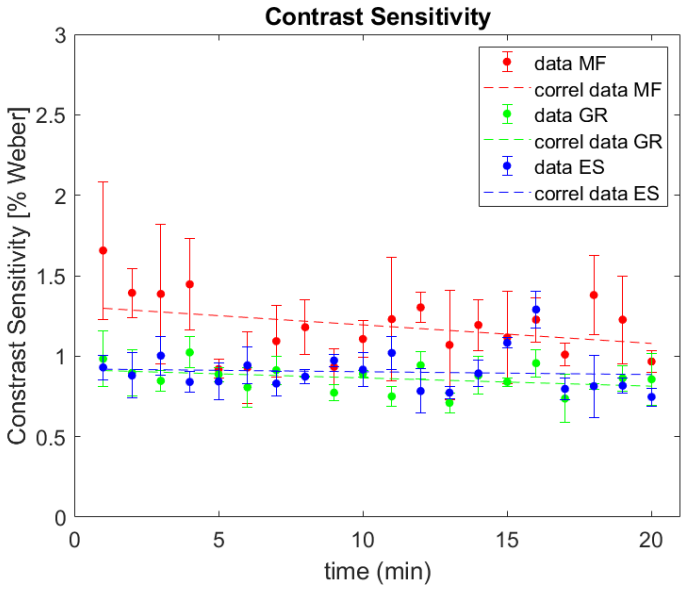
Once exposed to UV light, the lens activates quickly, and the transmitted intensity decreases abruptly with an initial characteristic time lower than 0.5 s for all the wavelengths.

Visual tests indoor (deactivation)

- 10 subjects (5 M, 5 W), 22-57 years old. 20 tests, 1 per minute, 3 times
- Software FrACT3.10.5 on a laptop, screen 15.6", distance 3 m, 15 trials per test:
  - **Visual Acuity(VA)**: Sloan letters (C, D, H, K, N, O, R, S, V, Z)
  - **Contrast Sensitivity (CS)**: tumbling Landolt 'C' (4 orientations)

e.g., 3 subjects (MF, GR, ES):





CORRELATION	GM	MF	M	MM	GR	ES	FK	LK	DT	AF
r(AV) [dec]	0,21	0,63	0,48	0,21	0,29	0,23	0,14	0,45	0,42	0,34
r(CS) [%Weber]	-0,19	-0,34	-0,24	-0,27	-0,37	-0,08	-0,28	-0,38	-0,22	-0,09

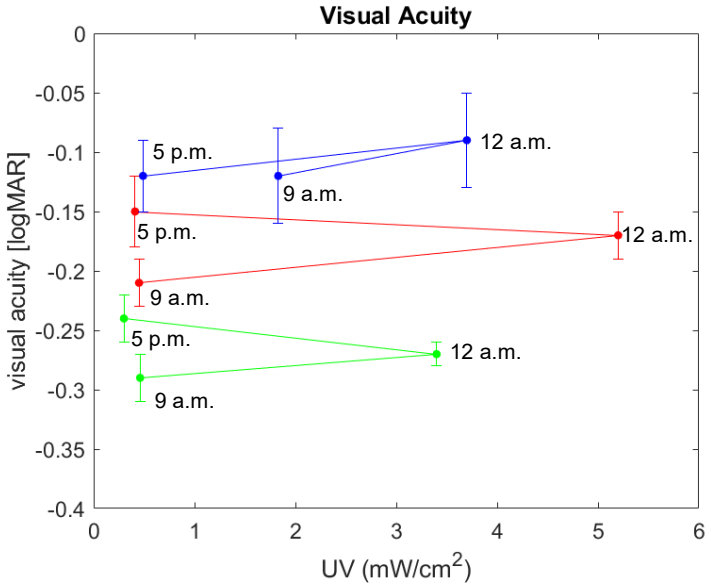
weak
average
strong

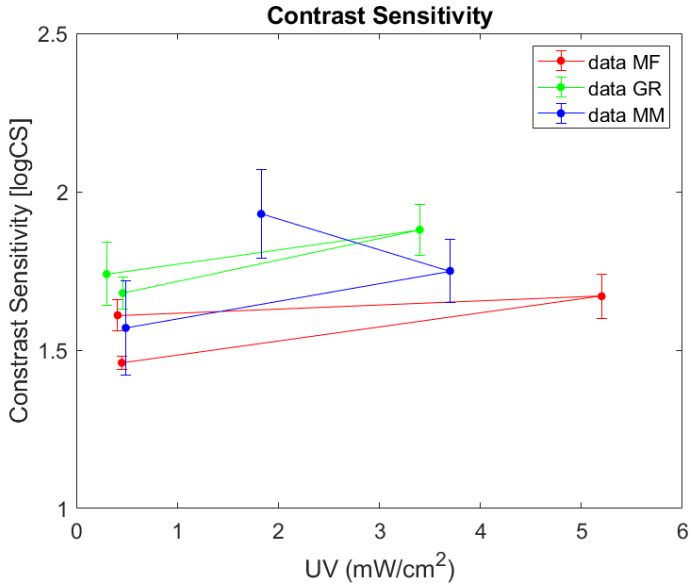
Good stability of visual performance in time. In general, weak correlation with time during lens deactivation: slight improvement of both VA and CS.

Visual tests outdoor (activation)

- Same group of subjects and same VA and CS tests (15 trials per test)
- Outdoor tests after activation: 3 tests (9 a.m., 12 a.m., 5 p.m.), 3 times, sunny days in mid-July (in Padova)
- UV sensor (GY/ML8511 + Arduino) to measure the UV intensity (280-390 nm) [mW/cm^2]

e.g., 3 subjects (MF, GR, EMM):





Preliminary tests suggest no strong influence on visual performance for all the subjects. The lens activation adapts to the UV level, as expected.

Conclusions

- We considered the commercial photochromic contact lenses ACUVUE OASYS with Transitions (J&J). We characterized the (de)activation process and performed preliminary tests on visual performances in terms of VA and CS.
- The lenses indeed adapt to the UV level in order to filter out the visible spectrum. High protection from UVA, UVB, and shorter visible wavelengths (blue light) is provided.
- The lens activates in a few seconds.
- Deactivation is quite longer, with an average characteristic time around 7 minutes.
- Weak influence on visual acuity and contrast sensitivity
- Practical and aesthetic consideration:
  - "*UV absorbing contact lenses are NOT substitutes for protective UV absorbing eyewear, […] because they do not completely cover the eye and surrounding area.*" (stated by the producer)
  - Most subjects under test report the need to wear also sunglasses, especially at noon, in addition to photochromic contact lenses.
  - Aesthetic aspect (critical for commercialization): when strongly activated, the contact lens covers the iris and gives the effect of an abnormally-wide pupil. Since we are not used to, that may appear weird and not appealing.

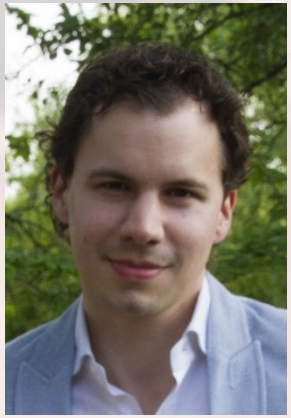
Thanks for your kind attention!



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