Effects on human health and the environment of systems using light-emitting diodes

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New sources of light

New usages of light

LEDs are now everywhere around us

At work

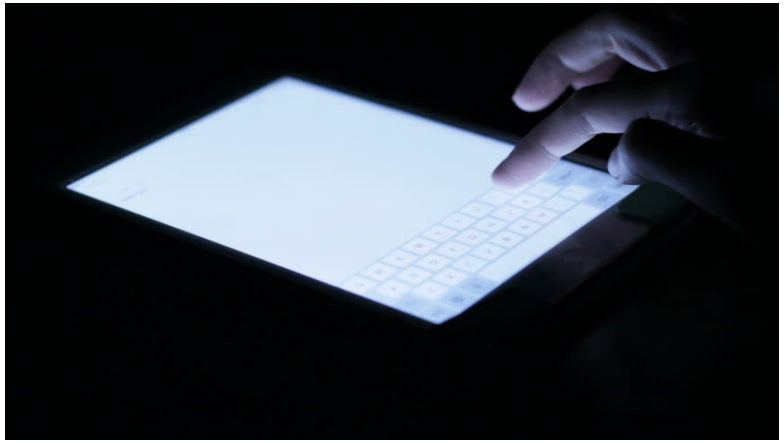
Outside

At home

Toys, gadgets

Car lighting

Flash lights, head lights



Displays

The ANSES report mainly deals with **negative impacts** of LEDs.

However, LEDs are theoretically **better than any other existing light source** to create **positive impacts** on health and environment, by delivering light :

- with an optimal spectrum for the given purpose
- with the good level (sometimes no light at all is the best option)
- with the appropriate timing
- at the right place

Potential effects of LEDs

1. **Effects on the eye**
2. **Disruption of circadian rhythms**
3. **Effects on sleep and alertness**
4. Effects on the skin
5. Effects of temporal light modulation
6. Effects on visual comfort and visual performances
7. Effects on light pollution and the environment – light pollution

focus on 1, 2 and 3 today

Effects on the eye

Effects on the eye

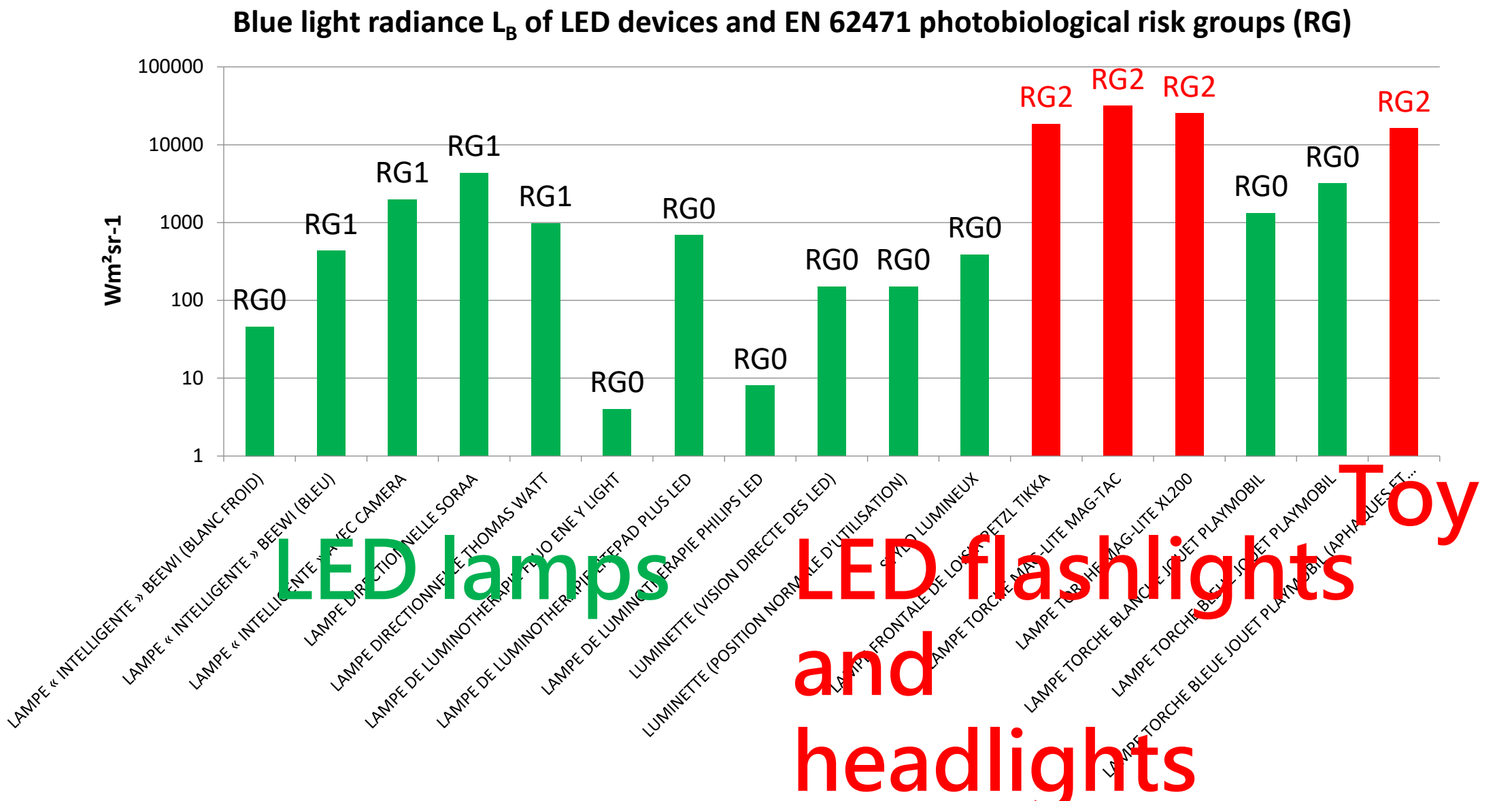
- **Proven** retinal phototoxicity of short term acute exposure to blue light (blue light hazard) in animal models and humans
- **Proven** retinal phototoxicity of short term acute exposure to high-CCT white LEDs on animal models
- **Proven** contribution of long-term cumulative exposure to blue light on Age Related Macular Degeneration (AMD)
  - Meta-analyzes of epidemiological studies considering exposure to solar radiation
- **Possible** effect of blue light exposure on the dry eye syndrome
- **Possible** effect of blue light exposure on the development of myopia

  (proven effect of exposure to daylight to prevent children from myopia)

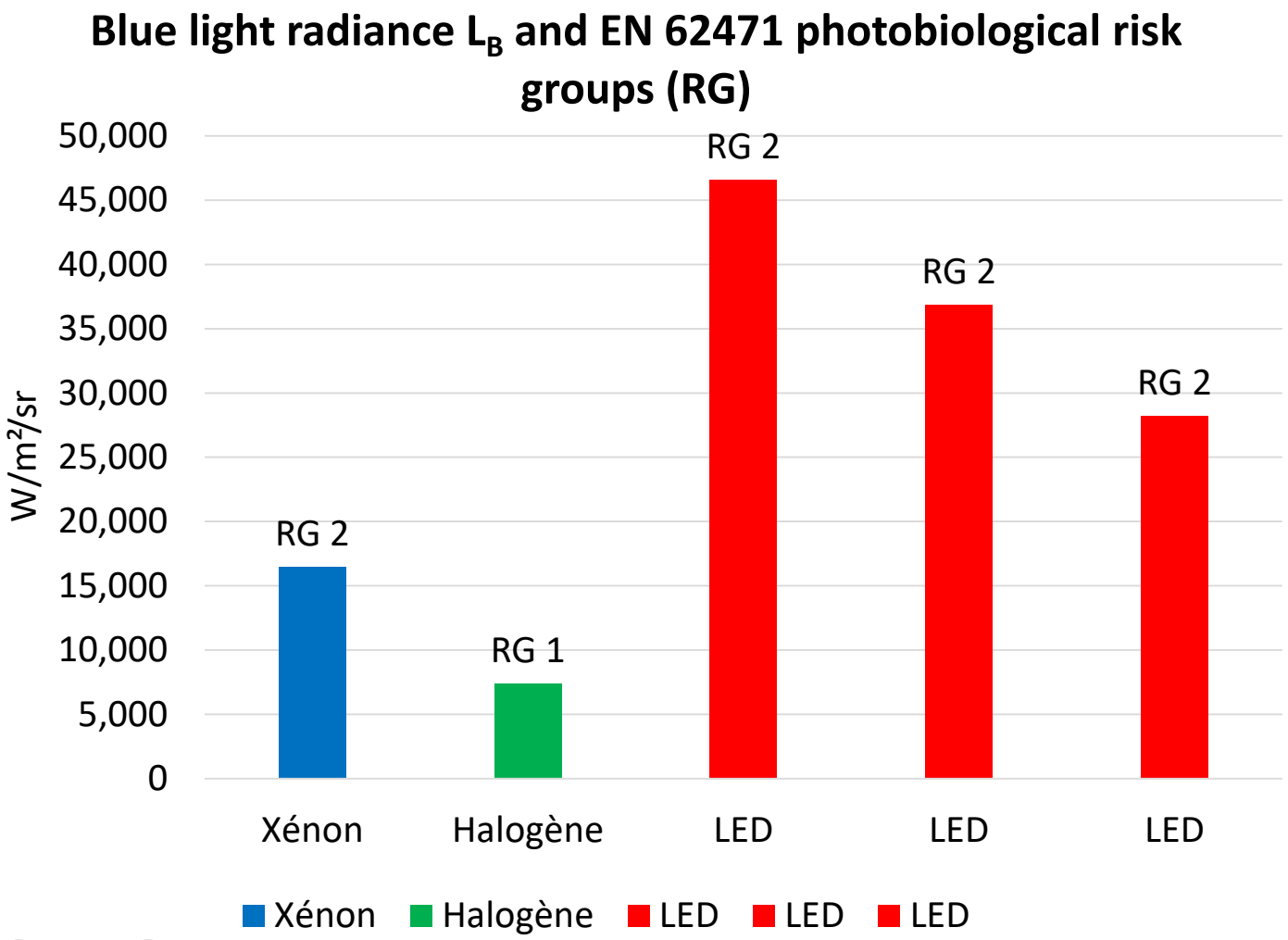
Sensitive population to ocular photoxicity

- People suffering from cognitive and motor control troubles with a reduced reflex of avoiding bright lights
- Professionals exposed to intense light sources (stage artists, lighting workers, dentists, surgeons, etc.)
- People suffering from ocular pathologies (dry eye, retinal pathologies, glaucoma)
- People without crystaline lens or with an artificial lens implant
- People taking photosensitive medication

Measurements of LED devices

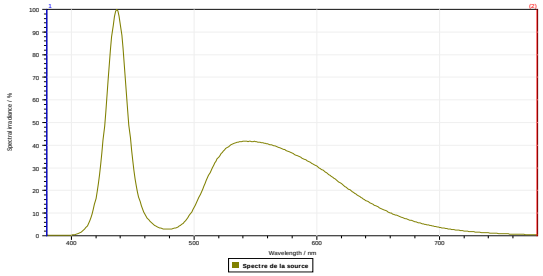


LED car headlights: low beams



Projecteur sur le support de mesure

Agrandissement sur le module du feu de croisement



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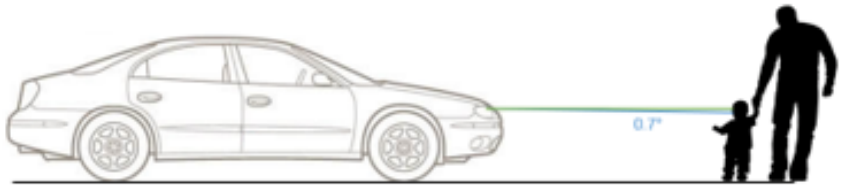
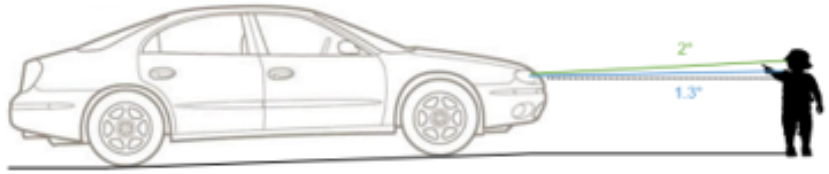
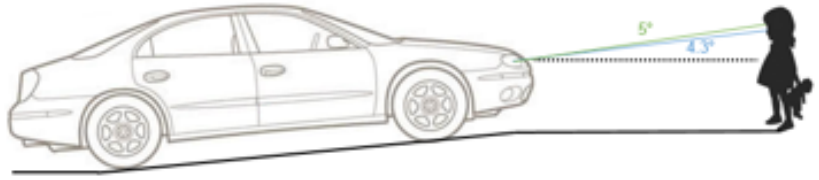
Exposure scenarios for car headlights



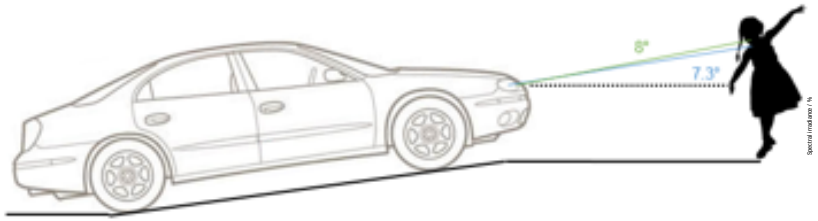
Cas a : véhicule à plat



Cas b : véhicule sur une pente de 3.5%



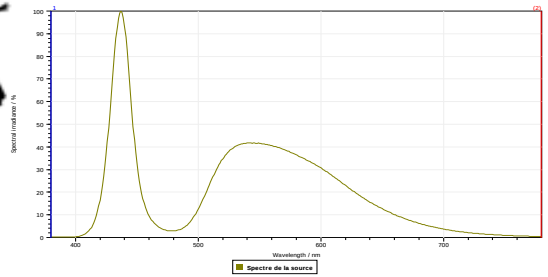
Cas c : véhicule sur une pente de 8.7%



Cas d : véhicule sur une pente de 14%

Projecteur sur le support de mesure

Agrandissement sur le module du feu de croisement



ld exposure

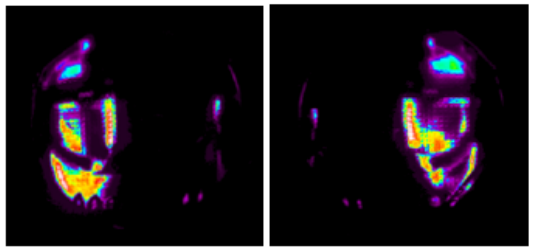
e of direct viewing is a
n of :

age (height)

tilt of the beam

slope of the road

ewing distances typically
n to 3 m for children



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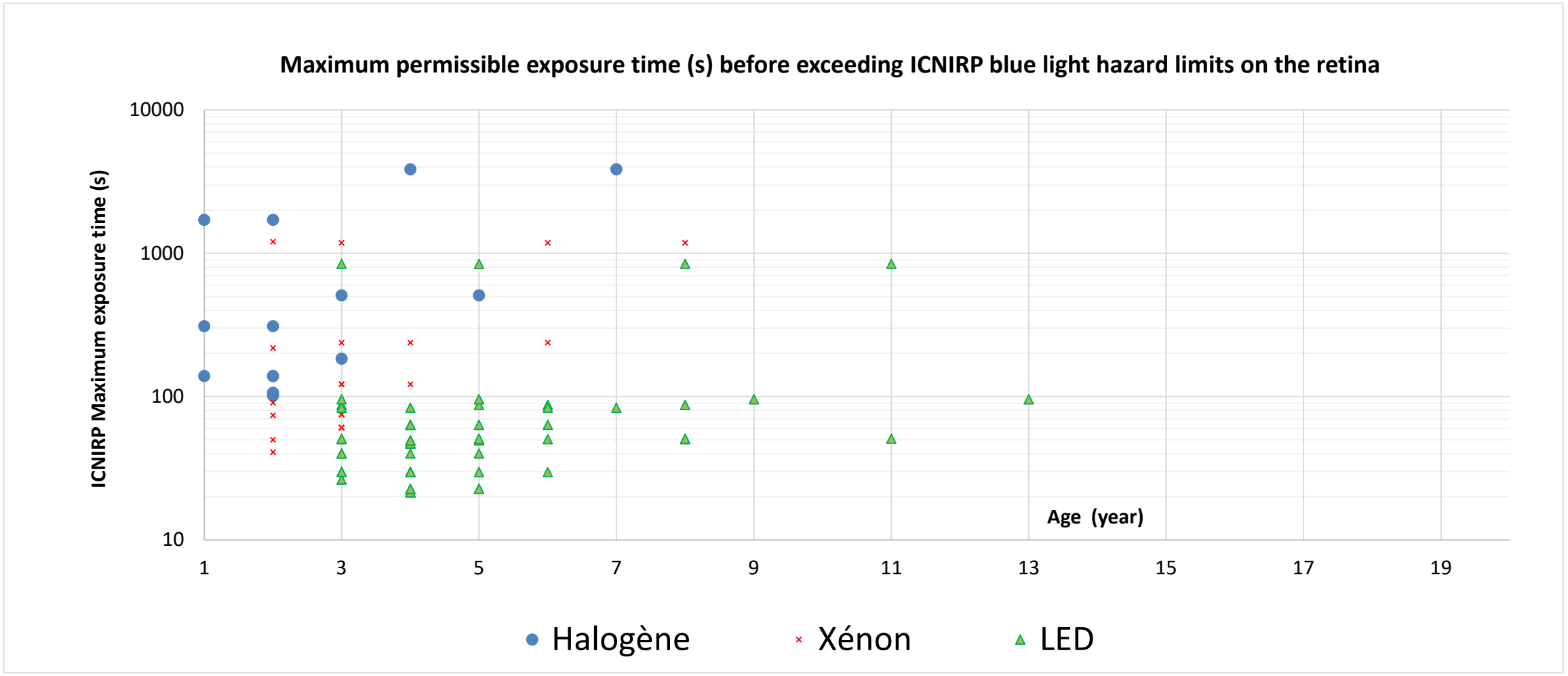
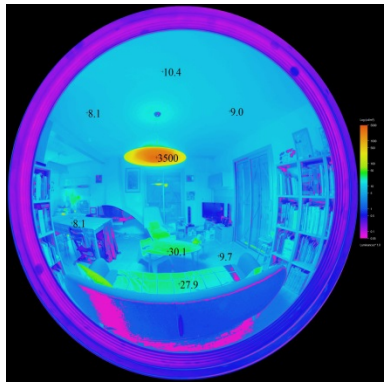
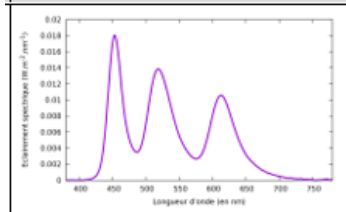
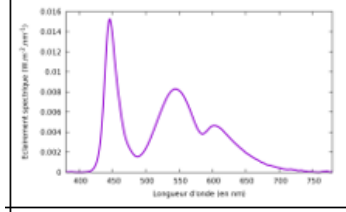
Significant increase of exposure to blue light hazard for children viewing LED low beams of car headlights



Characterization of long-term retinal exposure to environmental light

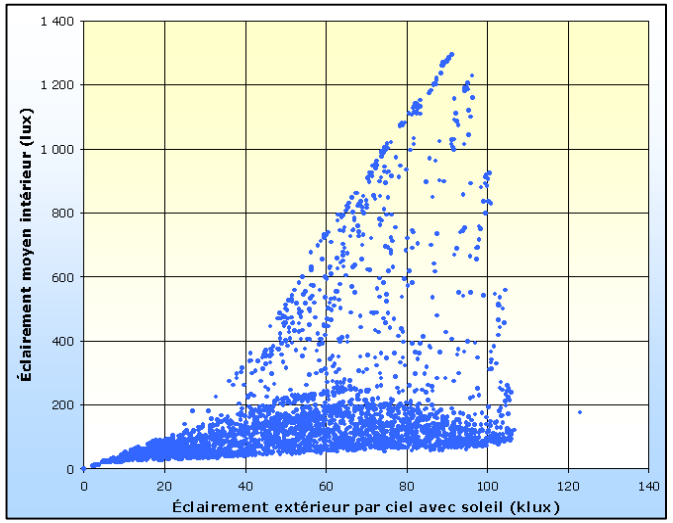


Photometric measurements

Distribution spectrale	Éclairement dans le plan de l'œil	Température de couleur
	10 lx	7 400 K
	8 lx	7 600 K
	10 lx	6 000 K

Living scenario and exposure schedules

Heure début	Situation	Environnement	Heure début	Situation	Environnement
[00:00:00]	sommeil	black room	[17:55:00]	trajet à pied	exterieur
[06:45:00]	bain	sdb	[18:00:00]	activite sportive	gymnase
[07:00:00]	petit dej	cuisine	[19:15:00]	trajet à pied	extérieur
[07:15:00]	brossage dents	sdb	[19:20:00]	trajet métro	black room
[07:20:00]	habillage	chambre enfant	[19:35:00]	trajet à pied	extérieur
[07:30:00]	trajet à pied	extérieur	[19:40:00]	bain	sdb
[07:35:00]	trajet métro	black room	[19:55:00]	activites domestiques	cuisine
[08:00:00]	travail de bureau	bureau	[20:30:00]	repas famille	salon



Climate-based daylight modeling

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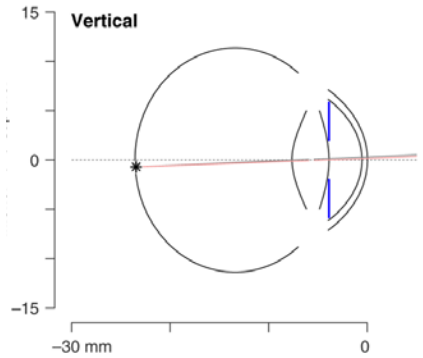
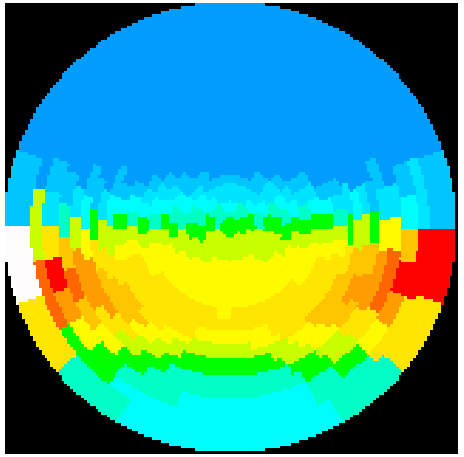
Characterization of retinal exposure

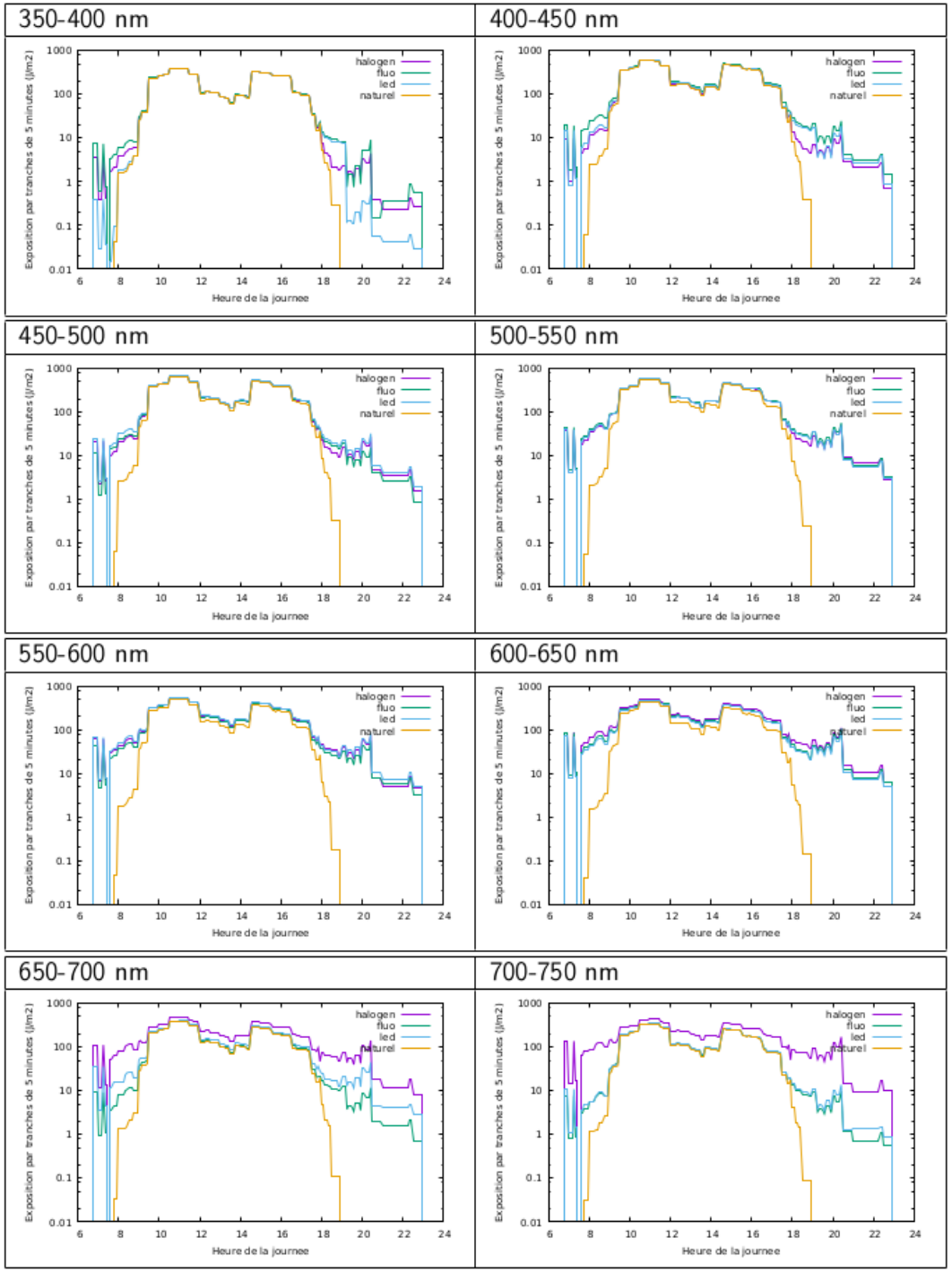


Eye optical model (Y. Le Grand)

Pupil diameter model (A. Watson)

Retinal exposure maps





Retinal exposure spectral/temporal profiles

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Results for a typical Parisian office worker

- Office located in Paris
- 6 to 8h of computer work , 5 days a week
- Holidays in Normandy and Côte d’Azur
- Regular leisure activities
- Shopping on the week-end
- Diversity of week-ends: sunny, rainy, etc.

Retinal exposure daylight vs. artificial light

Average daily retinal illuminance dose (lux.hours)

V(λ) weighting

in Winter :

- Daylight: 128 lx.h — More artificial light than daylight in winter
- Artificial light: 164 lx.h — Artificial light dose = 56% of total light dose

in Summer :

- Daylight: 413 lx.h
- Artificial light: 120 lx.h — Artificial light dose = 22% of total light dose

Influence of light source technologies on the blue light exposure

Average (over a year) daily retinal irradiance dose
B(λ) weighting

Limit value for BLH retinal damage (ICNIRP) : 2 200 mJ/cm²

Daylight: 102 mJ/cm²

Artificial lighting :

Halogen :	13 mJ/cm²	or 11% of total blue light exposure
Fluorescent :	27 mJ/cm²	or 21% of total blue light exposure
Low CCT LED :	23 mJ/cm²	or 18% of total blue light exposure
High CCT LED :	44 mJ/cm²	or 30% of total blue light exposure

Recommandations concerning phototoxicity

- ANSES recommends lowering BLH limit values set by ICNIRP
- The particular sensitivity of children in safety standards should be considered
- Limits of long-term cumulative exposure to blue light should be investigated
- Prohibit the use of intense blue and cold-white LEDs in toys, decorations, gadgets, etc. when they are accessible to children
- Introduce photobiological safety in automotive lighting regulations

Effects on circadian rhythms

Effects on circadian rhythms

- The disruption of circadian rhythms induced by exposure to artificial light in the evening or at night is **proven.**
- Blue wavelengths have a stronger effect on circadian rhythms.
- LED-based displays are the first contributors to the retinal exposure dose received in the blue part of the spectrum during the evening and at night.
- The circadian disruption has also been associated with many pathologies such as depression, cardiovascular disease, metabolic conditions, cancer and sleep disorders
- Not enough data to conclude about the role of LEDs in these pathologies

Effects on sleep

- Consequence of circadian disruption
- Proven effect of alteration of sleep quantity and quality after evening or night exposure to LED lighting and displays.
- The growing use of LED-based electronic displays have an impact on sleep quality by inducing or maintaining unhealthy sleep habits.

Sensitive population to circadian effects of LEDs

- Infants, children, adolescent, young adults
- Pregnant woman
- Elderly people (not enough melanopic excitation)
- People suffering from sleep problems
- Shift workers, night workers

Influence of light source technologies on the melanopic retinal exposure

Average (over a year) retinal illuminance dose during **2 h before bed time**
CIE-melanopic $s_z(\lambda)$ weighting
Parisian office worker scenario

Daylight:	0 z-lx.h
Artificial lighting :	
Halogen :	12 z-lx.h
Fluorescent :	10 z-lx.h
Low CCT LED :	11 z-lx.h
High CCT LED :	12 z-lx.h

Very similar melanopic doses for the different light sources

Recommandations concerning circadian effects

- limit exposure to artificial light 2h before bed time and during the night
- Increase exposure to daylight during the day
- Inform parents of the need to reduce exposure of children to lighting and displays before bed time

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https://www.anses.fr/fr/system/files/AP2014SA0253Ra.pdf

Technical appendices
https://www.anses.fr/fr/system/files/AP2014SA0253Ra-Anx.pdf)

Official ANSES opinion (24 pages), available in French and English at
https://www.anses.fr/fr/system/files/AP2014SA0253EN.pdf