Report

Simulations with rat eye model

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1 Input selection

Among the various available measurements to be simulated, we consider that of blue light, due to the simplicity of the source spectrum. For simplicity, we will model the light source as a coherent light source. The known and derived data of the source are listed in the Table 1.

Light source parameter	value
λ [nm]	449
E_v [lx = lm/m^2]	639
$E^{[1]}$ [mW/cm^2]	~ 0.7
$L^{[2]}$ [mW/cm^2/sr]	~ 0.2
W$_s$ [cm] (*width*)	78
L$_s$ [cm] (*length*)	50
A$_s$ [cm^2]	3900

Cage parameter	value
W$_c$ [cm] (*width*)	28
L$_c$ [cm] (*length*)	41.5

Table 1: Light source (blue led) and cage parameters.
[1]: calculated with a luminous efficiency of 90 lm/W (standard led), in the absence of the original irradiance data.
[2]: calculated under the assumption of isotropic source.

2 Reference eye model

For simulations, the schematic rat eye model described in [BTAT13] is used. The parameters related to this eye model are shown in Table 2, while a virtual representation of optical surfaces of the eye model are shown in Figure 1. Total transmittance is always set to 58% and the pupil has a constant diameter of 5 mm.

component	R [mm]	p [mm]	$n(\sim 449^{[1]})$
cornea (front)	3.051	0.0	1.3882
cornea (back)	2.959	0.156	1.3381
lens (front)	2.535	0.864	1.6974
lens (back)	-2.441	4.678	1.3379
retina	3.543	6.087	-

Table 2: Parameters of the rat eye model described in [BTAT13]. Position p is relative to the cornea (front).
[1] calculated through a second-order linear fit (in line with the Cauchy equation).

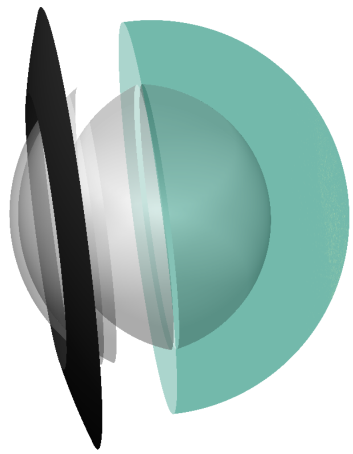


Figure 1: Virtual representation of the rat eye model described in [BTAT13] and used for simulations. The green surface corresponds to the retina, while the black ring represents the pupil (always set to an aperture of 5 mm).

3 Simulation design

The setup involves the use of a cage, inside which the rat can move freely, and a diffuse light source placed 25 cm above the rat (H). A total of two cages can be positioned below the light source. Therefore, the light that illuminates each individual cage is asymmetrical. Figure 2 shows a representation of the cage and the light source above.

The position of the rat is unknown, making it impossible to derive more probable positions or average positions. Consequently, directly determining the received dose after 2 hours of exposure as a unique value is not feasible. Instead, we can estimate the exposure for "average" positions. This allows creating a "distribution" of received doses, enabling comparison with experimental results.

The main assumption we make is that the rat's gaze direction is always horizontal, meaning the optical axis of the eye lies in the horizontal plane.

We selected 3 different positions for which to calculate the distribution of irradiance on the retina and the corresponding radiant dose. The positions are shown in Figure 2 on the horizontal plane of the cage. They were chosen based on the size of the cage, average distances between marginal points and different resulting distributions. In more detail, the three points are located at the midpoint of the cage's width ($W_c/2$) and at their respective quarters of the length ($L_c/4$, $L_c/2$, $3L_c/4$).

A total of 10 million light rays (10^7) are generated for each position. For each position, the total irradiance was calculated from the irradiance distribution. The radiant dose received was computed by multiply the exposure time (i.e., 7200 seconds).

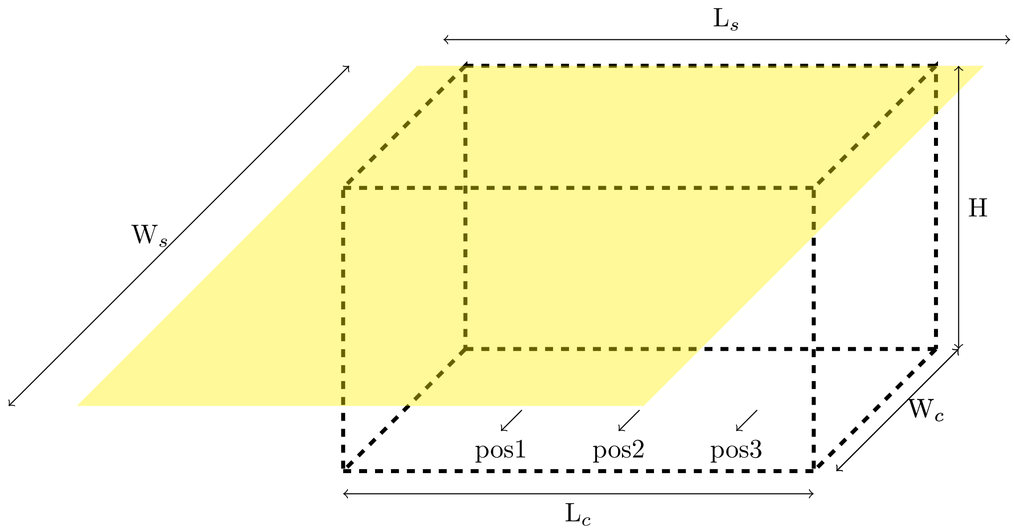


Figure 2: Schematic representation of the cage (dashed line) and the light source (yellow surface). The height H corresponds to the distance between the light source and the rat's position (25 cm).

4 Results

The results are shown in Figure 3, while the corresponding values of radiant dose are reported in Table 3.

The values of radiant dose are quite compatible with those derived from the experiment, as the order of magnitude is similar to that recorded in the experimental measurements. The maximum value is calculated at position 2, centrally with respect to the length of the light source, where the emitting surface is in the configuration where it is maximal (64 cm × 50 cm = 3200 cm^2).

For the distribution, it is noticeable how it differs from that recorded in the experiment. In the measurements, indeed, an energy formation in the upper part of the retina was observed. No displacement of the distribution on the upper part of the mouse retina is observed at any other eye position within the cage. Even when bringing the eye close to the cage's edges or rotating it to vary the visible light source surface, the distribution will always be on the lower part of the retina.

In the simulations, double internal transmissions on the lens (back) were also considered, trying to understand the experimental result. However, in any of the chosen positions, the rays are at most reflected towards the front surface of the lens, and never onto the retina. Anyway, even if they were transmitted to the retina after a double internal transmission, the intensity would be so low as not to explain the peak of energy recorded in the experimental measurements.

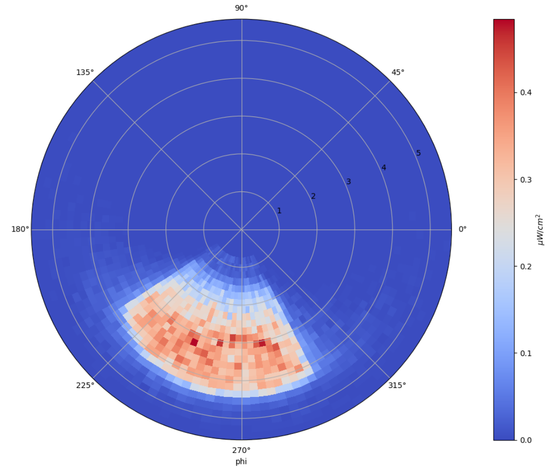
The exposure time does not vary the size of the damaged area, as it only pertains to the optical variables of the model. The source's intensity is related to the intensity received on the retina, but not its distribution.

position	J/cm^2
pos 1	0.90 ± 0.5
pos 2	1.04 ± 0.5
pos 3	0.89 ± 0.5

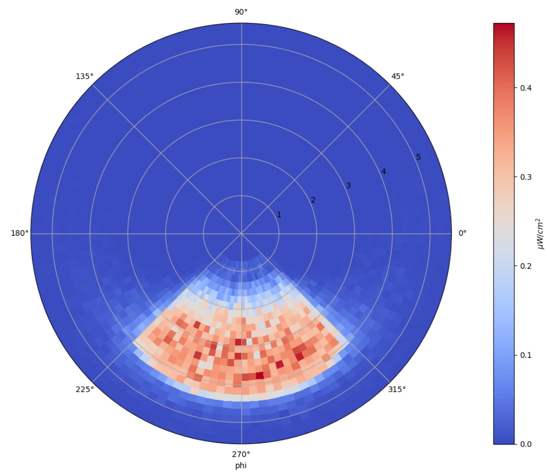
Table 3: Values of radiant dose calculated for each simulated position. The values are calculated considering an exposure of 2 hours (i.e., 7200 seconds).

References

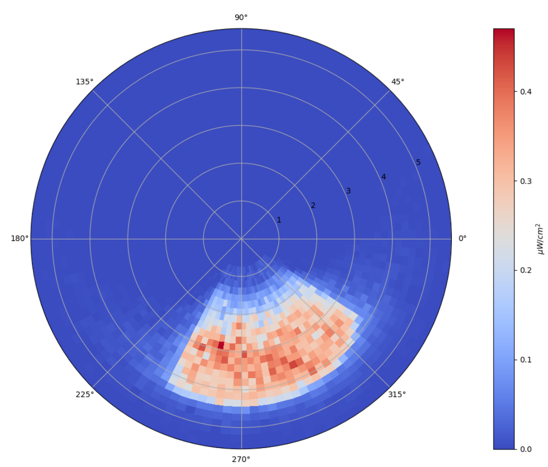
[BTAT13] Gurinder Bawa, Tatiana Tkatchenko, Ivan Avrutsky, and Andrei Tkatchenko. Variational analysis of the mouse and rat eye optical parameters. *Biomedical optics express*, 4:2585–2595, 11 2013.



(a) pos 1



(b) pos 2



(c) pos 3

Figure 3: Polar plot of retinal irradiance distributions for the 3 selected positions. The horizontal axis corresponds to the temporal-nasal axis of the rat's eye, while the radial variable corresponds to the distance (in mm) from the center of the retina.