Aging of the Human's Ocular Media and Blue Light Effects from Different LED Sources

Kamelia Nikolova, Iva Petrinska, Dimitar Pavlov, Petya Djanovska

Technical University of Sofia

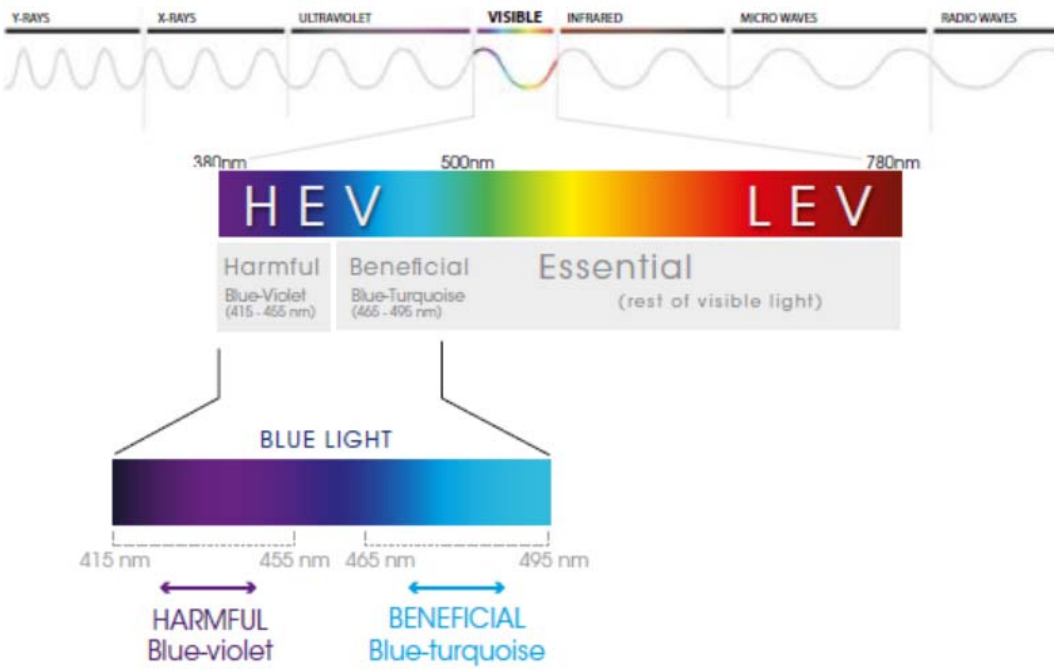


Fig. 1 Electromagnetic spectrum and optical radiation

The human eye is adapted to function in conditions of optical radiation. This radiation not only enables vision, but influences important physiologic functions. The radiation in the short-wavelength visible spectrum is characterized by the highest amount of photon energy. It includes harmful blue-violet (415-455 nm) and beneficial blue-turquoise radiation (465-495 nm), involved in the proper functioning of the metabolism in humans (circadian rhythms and endocrine activities).

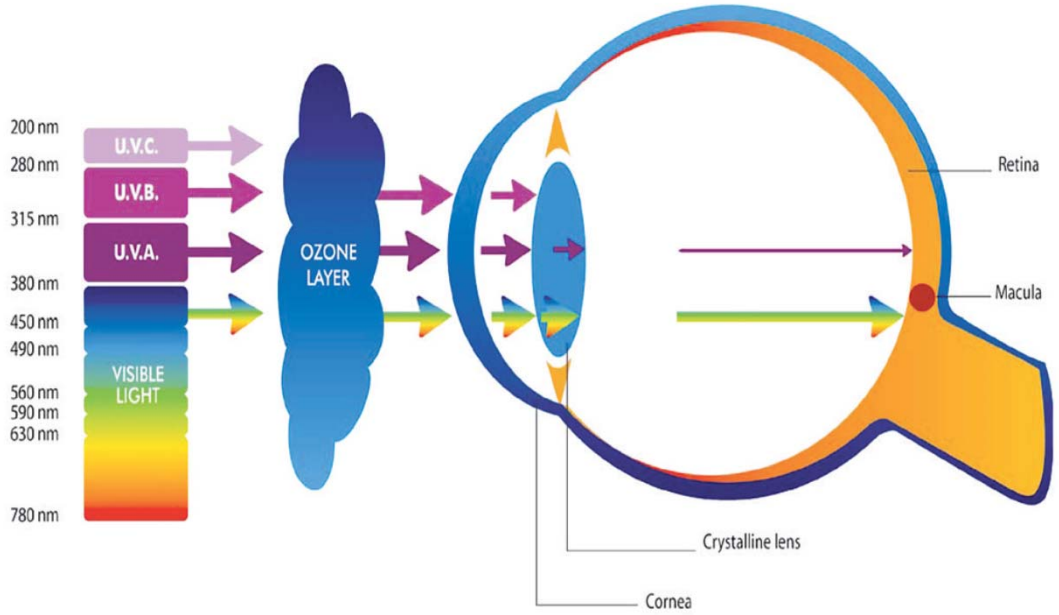


Fig. 2 Absorbtion and transmission of solar radiation in the eye

The human eye is subject to harmful and positive effects, both acute and long-term exposure to optical radiation from the sun, artificial light sources and digital devices.

The composition of the radiation is filtered by the cornea or the crystalline lens.

The healthy human eye has a natural protection against UV radiation, but in terms of radiation in the visible part of the spectrum there aren‘t available natural defense mechanisms.

Influence of the radiation in the blue part of the spectrum

✓ Positive effects (465-495 nm)

Radiation in the blue part of the spectrum is important not only for the color perception, but for many non-visual processes. They include circadian entrainment, melatonin regulation, pupillary light reflex, cognitive performance, mood, locomotor activity, memory and body temperature.

X Negative effects (415-455 nm)

Photochemical damage and toxication of the retina can appear both acute and long term exposure to solar radiation and artificial lighting sources, in particular to radiation in the blue part of the spectrum.

Sources of optical radiation in the blue part of the spectrum

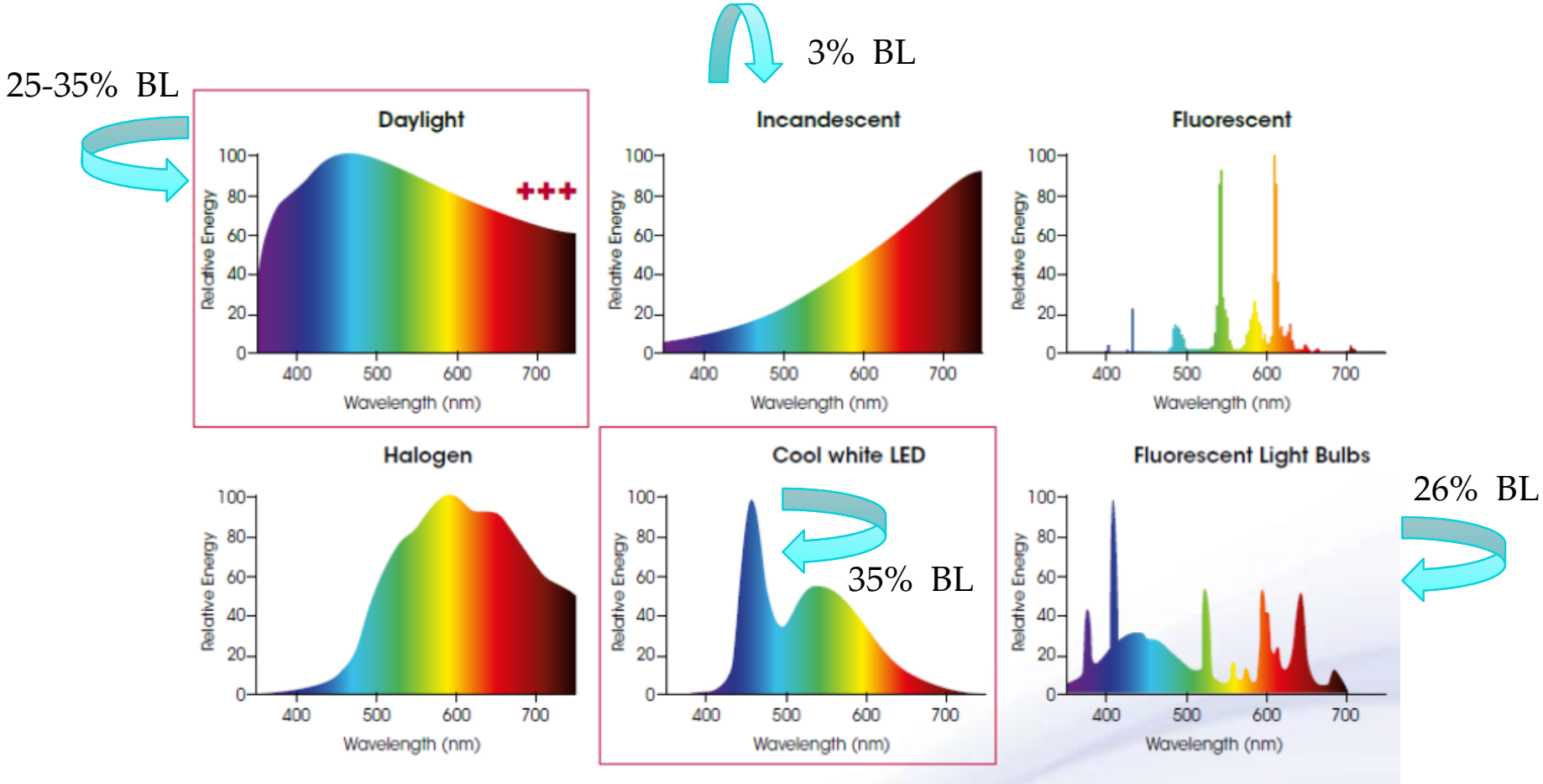


Fig. 3 Emission spectrum of various light sources including cold-white LED

Mechanisms of retinal damage and phototoxicity

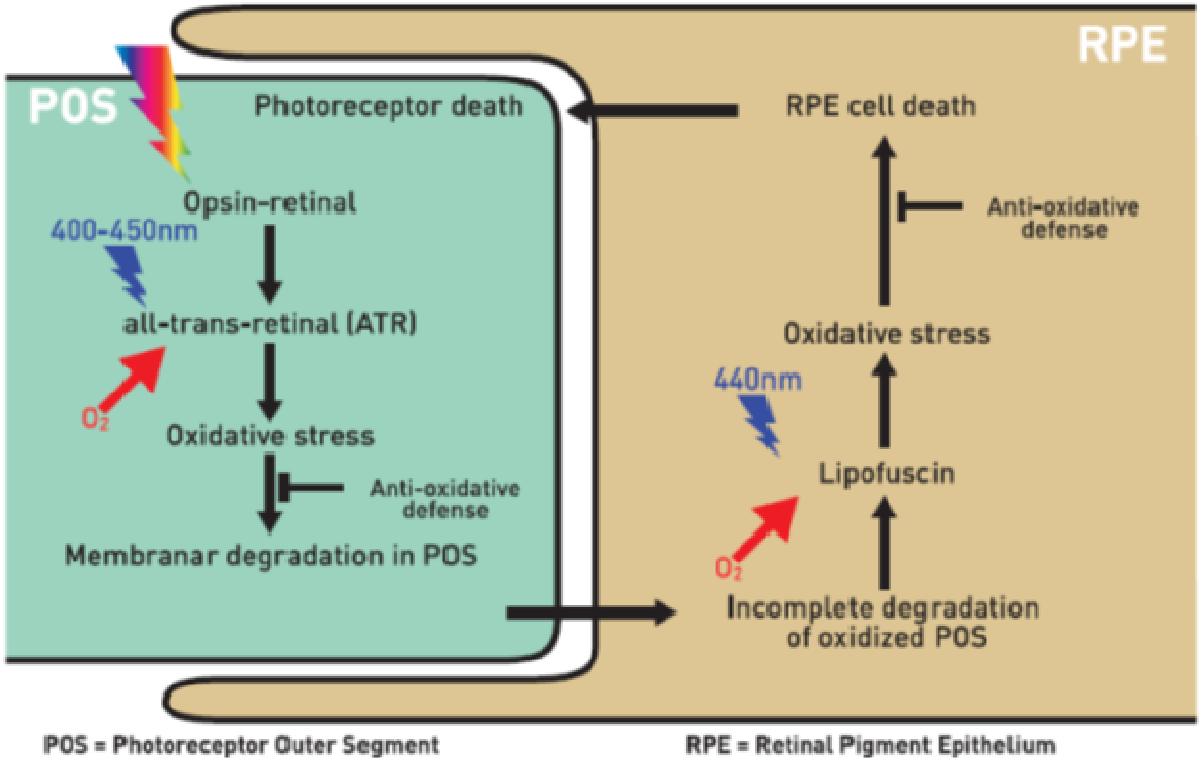


Fig.4 Phototoxicity mechanisms in outer retina [1]

The photochemical damage is caused by accumulation of the waste product lipofuscin in the granules of retinal pigment epithelium cells. Lipofuscin (also known as age pigment) accumulates with increasing age, and also in certain diseases of the retina.

Aging and optical radiation transduction of the ocular media

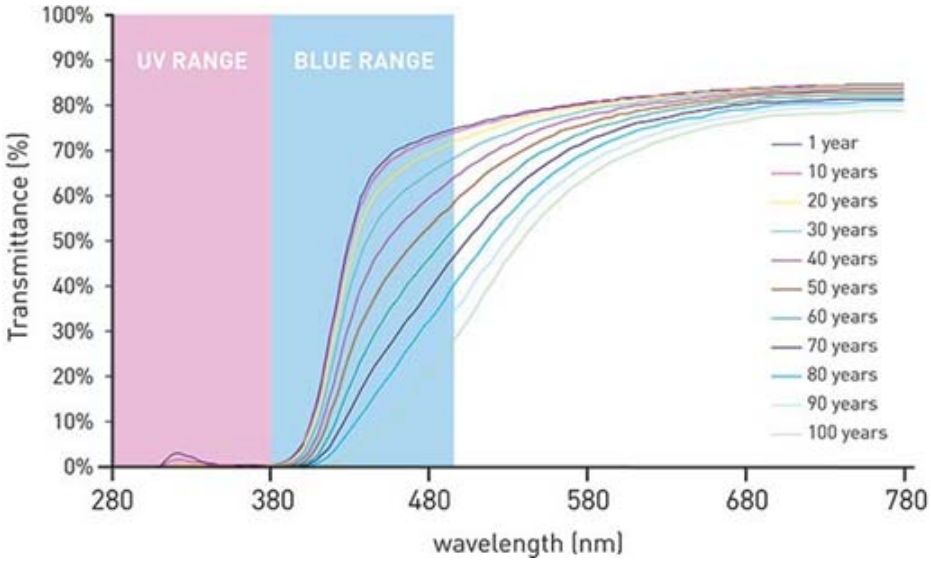


Fig.5A: Total transmittance of clear ocular media of aging human eye. Fitted from the CIE 203:2012 data

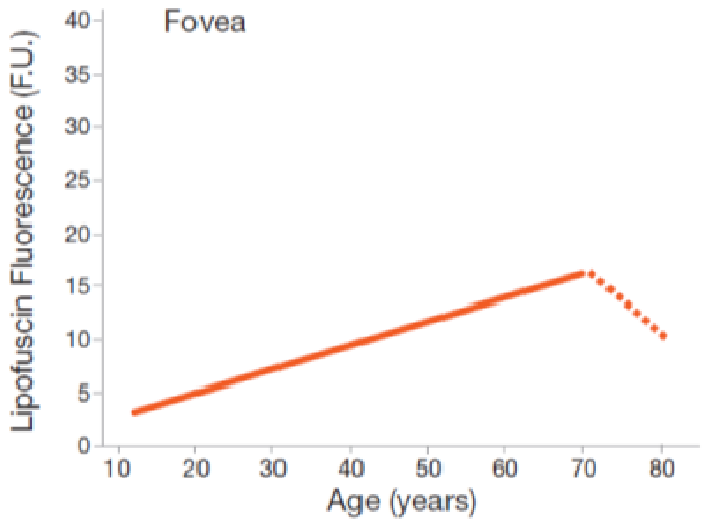


Fig.5B Lipofuscin levels in the human fovea increase with age

As the eye ages, light transmission and absorption change, primarily owing to the gradual yellowing of the crystalline lens. As a result, the aging lens transmits less visible light overall, with a disproportionate drop in transmission of blue light due to yellow discoloration of the lens, fig. 5.

Aging and optical radiation transduction of the ocular media

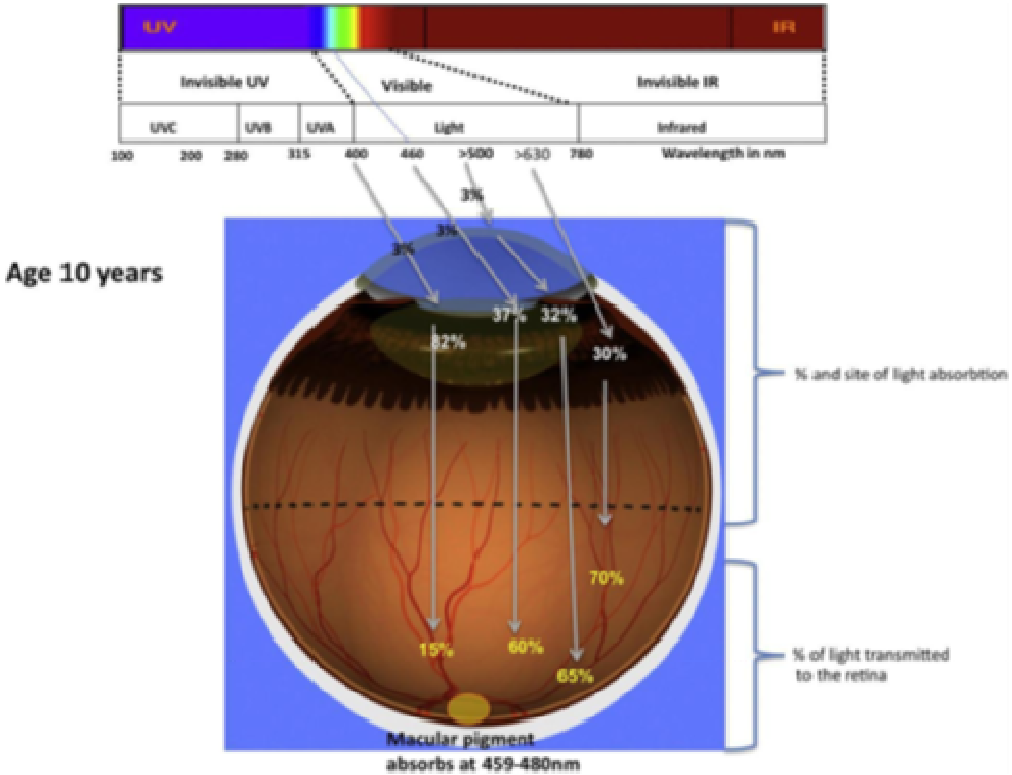


Fig.6: Interaction of visible light (www.sciencedirect.com, Behar-Cohen et al. (2011))

Lipofuscin starts to accumulate in the earlier ages and becomes visible in the retinal pigment epithelium cells of a healthy 10 years old human being, fig. 6.

Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum

The purpose of the study is to assess the impact of age-related changes in the characteristics of the ocular media on the possible risks from radiation in the blue part of the spectrum from different LED sources. On the other hand, of particular interest are comparative analysis of the non-visual influence on the melanopsin photoreceptors reaction, which is connected with a direct impact on the circadian rhythms.

For comparison reasons **the results** from the research are represented **for equal illuminances over the measurement plane** and the corresponding field of views, defining the angular subtense of the lighting sources. The specific characteristics of the products have been taken into account. The luminance of the sources is defined according p.5.2.2.2 of EN 62471.

Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum

Experimental survey of the radiated spectrum has been done with calibrated radiometer Stellar Black Comet (wavelength range 200-1100 nm) and complying with EN 62471 and IEC/TR 62778.

No	Description		Power	CCT, defined from measured spectrum	L_B, W/(m^2.sr)
1	LED retrofit bulb		7 W	3026 K	12,03
2	LED recessed luminaire with glass optics		29 W	3510 K	23,91
3	LED recessed luminaire frosted		100 W	5256 K	41,91
4	LED retrofit bulb		7 W	5744K	70,23

Table 1 Measured LED lighting sources

Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum

For evaluation of the potential age-related blue light hazard is defined the radiance $L_B(\tau)$, weighted with the standard blue light spectral sensitivity function $B(\lambda)$, fig. 7A, and the age-related functions of total transmittance of the ocular media $\tau(\lambda)$.

Melanopic irradiance quantity $E_{E,z}(\tau)$ is defined by the irradiance from the sources, weighted with the spectral sensitivity function of the intrinsically photosensitive retinal ganglion cells $s_z(\lambda)$, fig. 7B, and the age-related functions of total transmittance of the ocular media $\tau(\lambda)$.

The influence of the age-related changes in the ocular media and the corresponding coefficients of total transmittance of optical radiation are adopted from the data, shown on fig. 5A

Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum

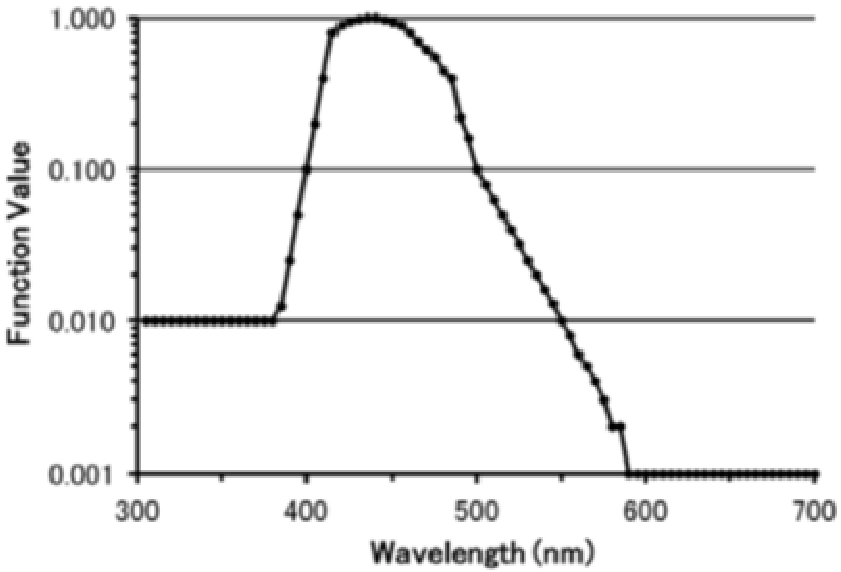


Fig.7A: Spectral weighting function for blue light retinal hazard B(λ)

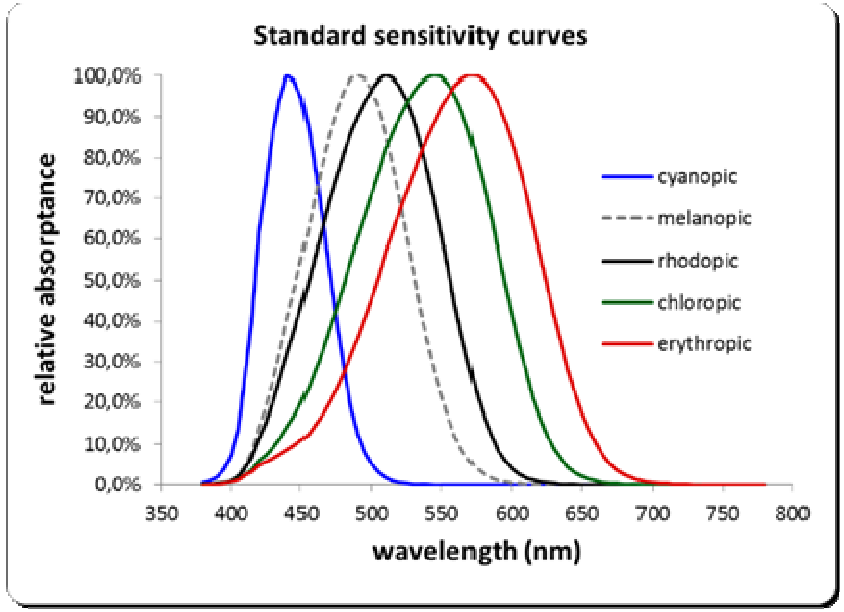


Fig.7B Standard sensitivity curves for the different human retinal photopigments

Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum

Numeric values for $L_B(\tau)$, W/(m^2.sr), for the different age groups are calculated from:

$$L_B(\tau) = \sum_{300}^{700} L(\lambda).B(\lambda).\tau(\lambda).\Delta\lambda, \qquad (1)$$

where $L(\lambda)$ is the spectral radiance, W/(m^2.sr.nm); $B(\lambda)$ is the blue light hazard weighting function; $\tau(\lambda)$ is the age-related total transmittance function of the ocular media and $\Delta\lambda$ is the bandwidth, nm

Numeric values for age-related spectrally weighted melanopic irradiance $E_{E,\lambda}(\tau)$, μW/cm^2, are calculated from:

$$E_{E,z}(\tau) = \sum_{300}^{700} E_{E,\lambda}(\lambda).s_Z(\lambda).\tau(\lambda).\Delta\lambda, \qquad (2)$$

where $E_{E,\lambda}(\lambda)$ is the spectralirradiance, μW/(cm2.nm); $s_z(\lambda)$ is the spectral sensitivity function of the intrinsically photosensitive retinal ganglion cells; $\tau(\lambda)$ is the age-related total transmittance function of the ocular media and $\Delta\lambda$ is the bandwidth, nm.

Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum

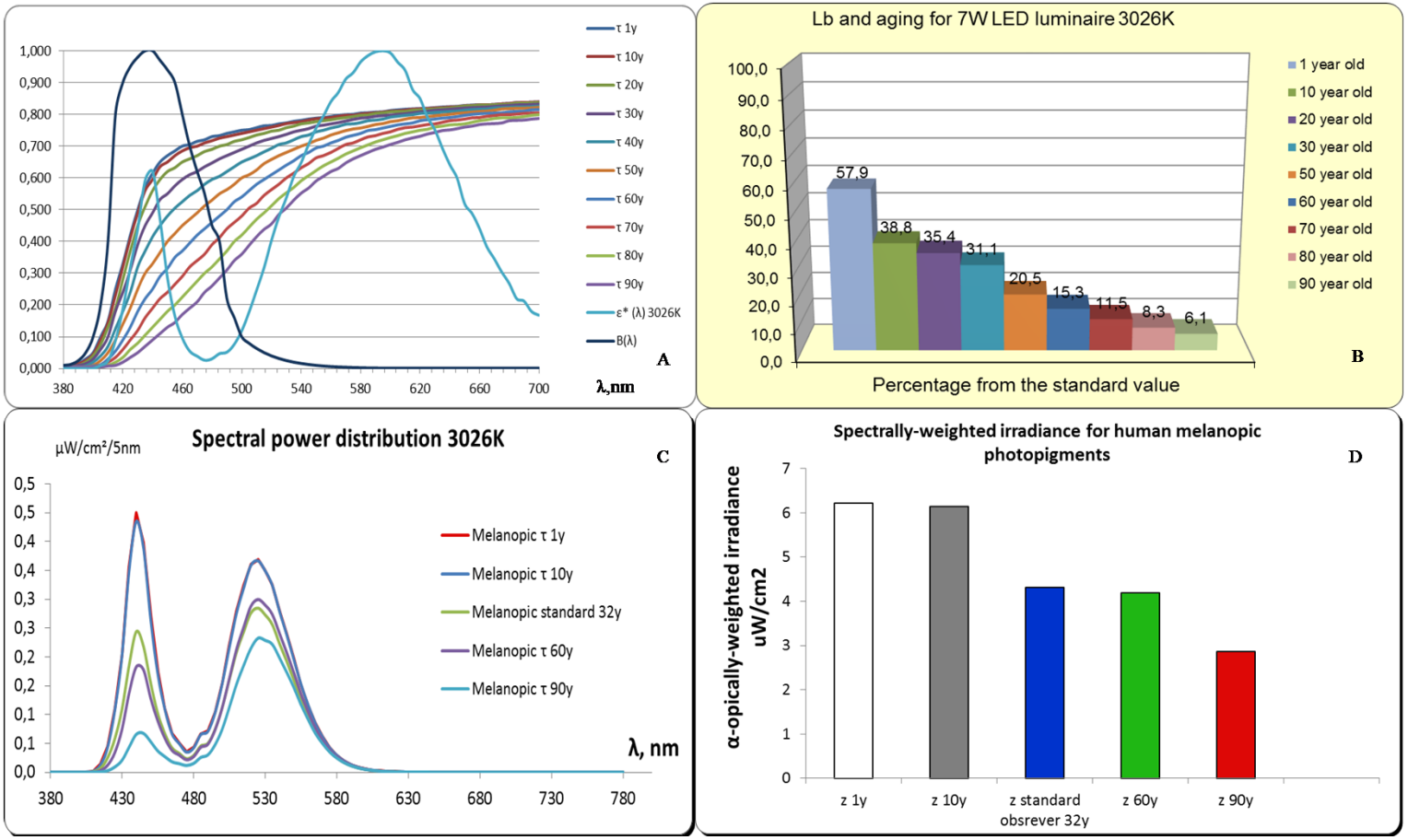
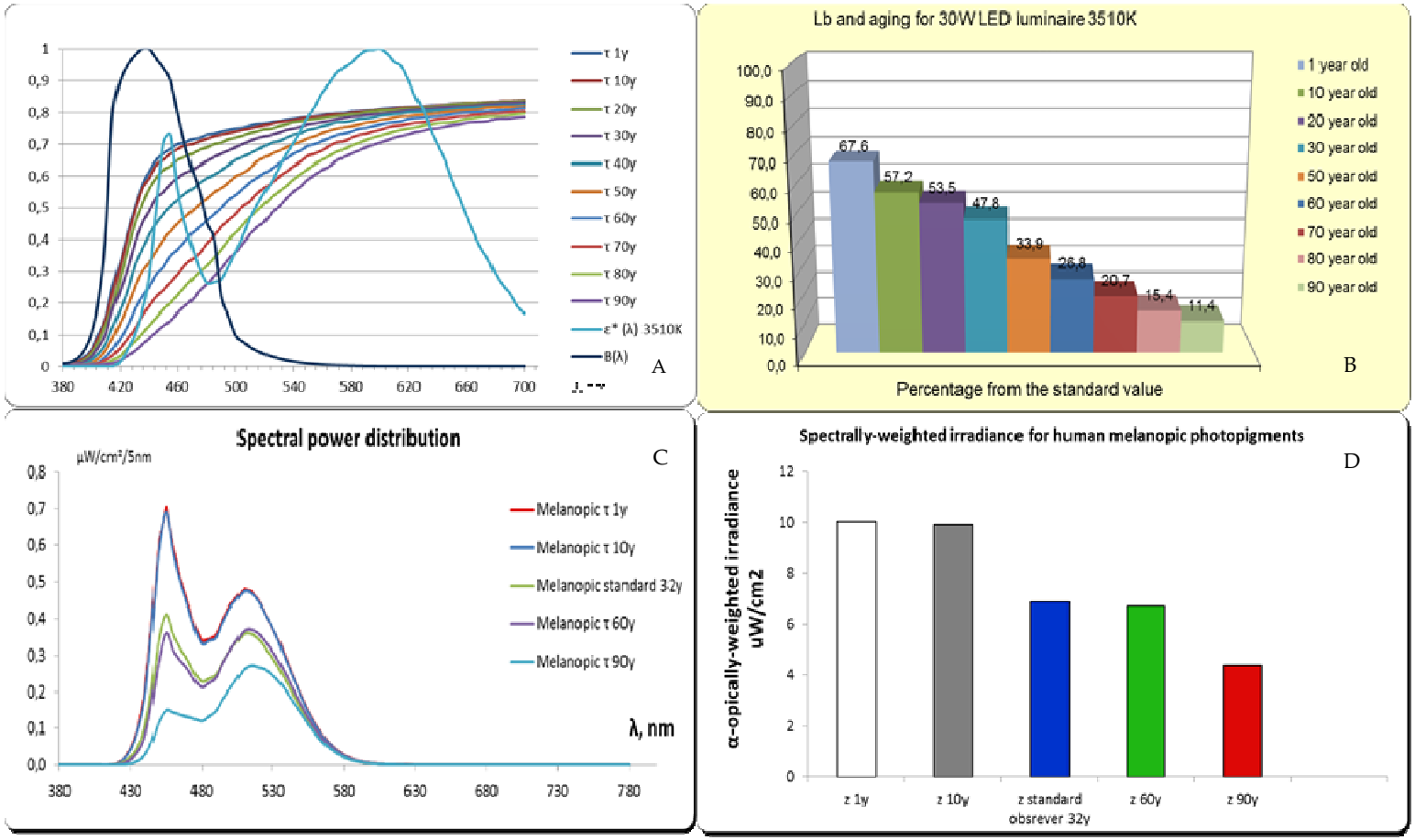


Fig. 8 Results for LED retrofit bulb with radiation spectrum, corresponding to CCT 3026K

A. Relative values for the measured irradiance from the LED source ε(λ), B(λ) and age-related τ(λ)*
B. Age-dependency of the determined values for L_B
C. Age-related spectral power distribution weighted for human melanopic photopigments
D. Age-related spectrally weighted irradiance for human melanopic photopigments

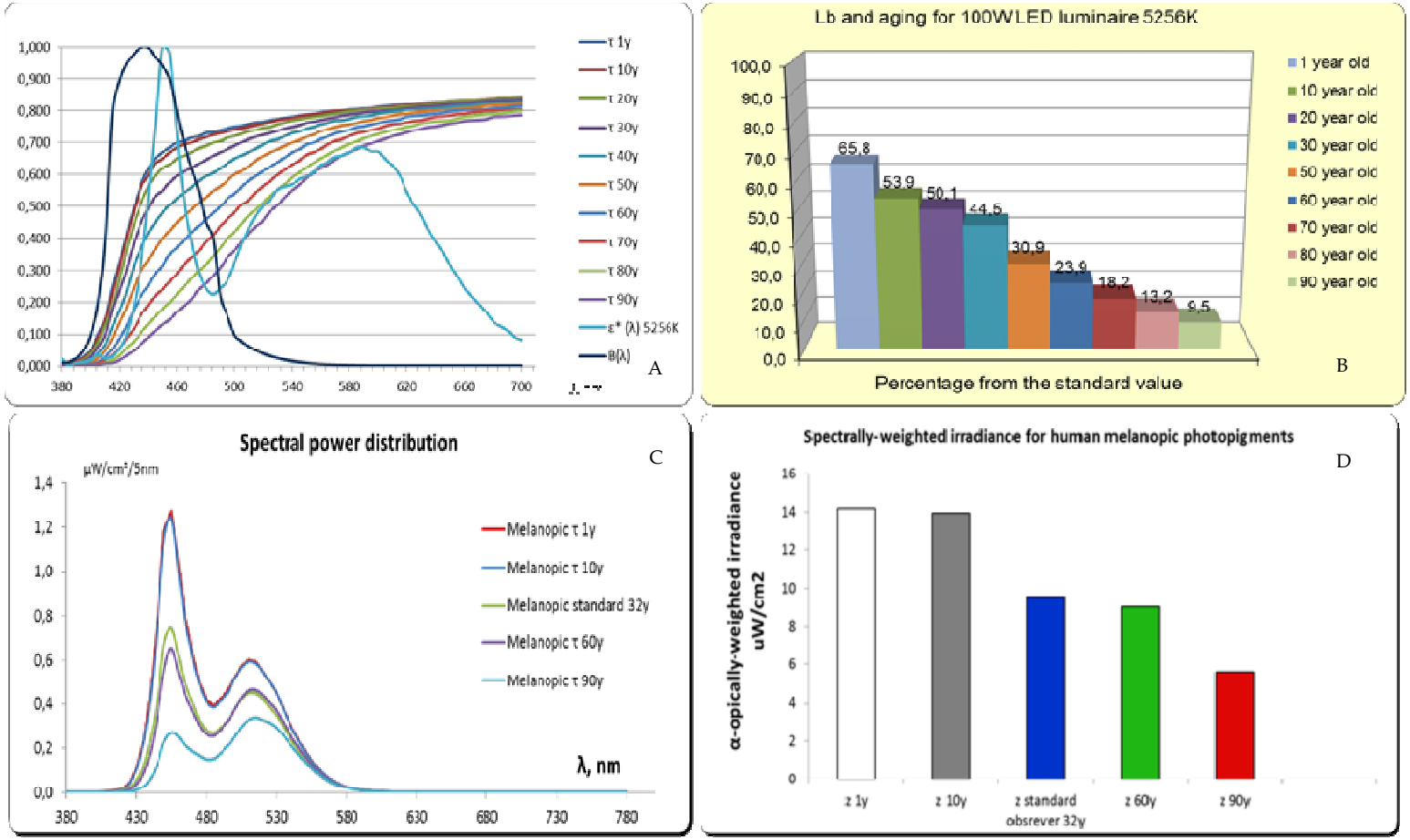
Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum



A. Relative values for the measured irradiance from the LED source ε(λ), B(λ) and age-related τ(λ)*
B. Age-dependency of the determined values for L_B
C. Age-related spectral power distribution weighted for human melanopic photopigments
D. Age-related spectrally weighted irradiance for human melanopic photopigments

Fig. 9 Results for LED recessed luminaire with glass optics and radiation spectrum, corresponding to CCT 3510K

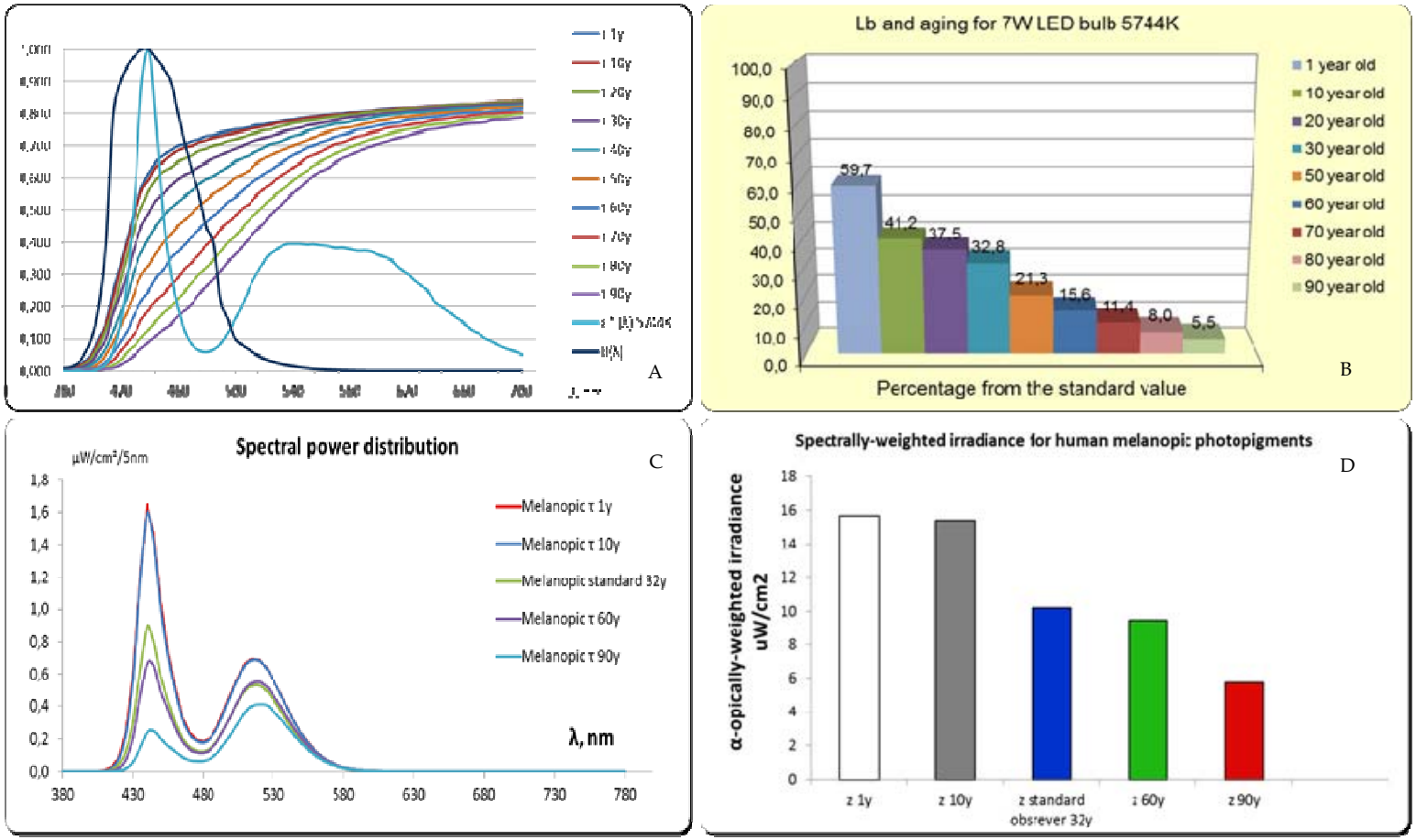
Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum



A. Relative values for the measured irradiance from the LED source ε(λ), B(λ) and age-related τ(λ)*
B. Age-dependency of the determined values for L_B
C. Age-related spectral power distribution weighted for human melanopic photopigments
D. Age-related spectrally weighted irradiance for human melanopic photopigments

Fig. 10 Results for LED recessed luminaire, frosted with radiation spectrum, corresponding to CCT 5256K

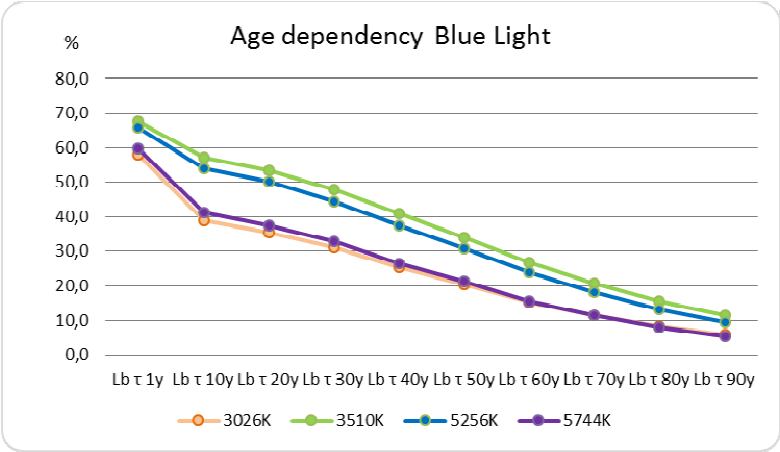
Research on the influence of age on the transmission of optical radiation in the blue part of the spectrum

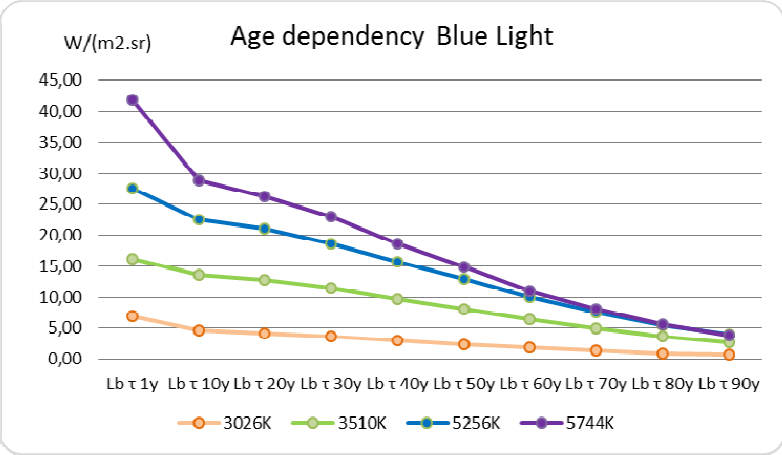


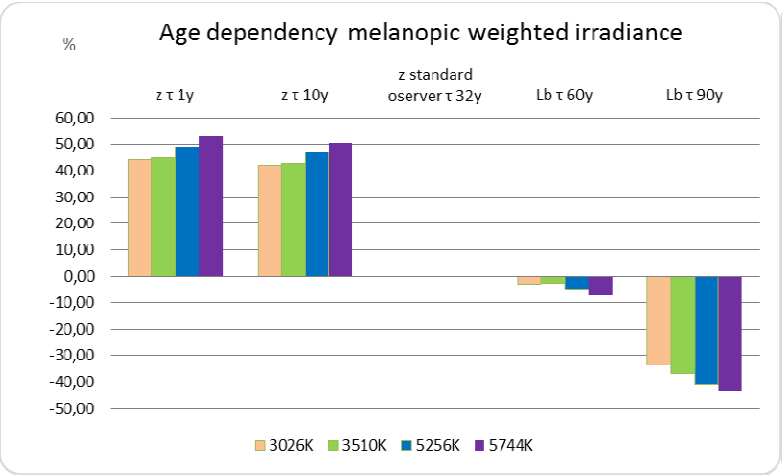
A. Relative values for the measured irradiance from the LED source $\varepsilon^*(\lambda)$, $B(\lambda)$ and age-related $\tau(\lambda)$
B. Age-dependency of the determined values for L_B
C. Age-related spectral power distribution weighted for human melanopic photopigments
D. Age-related spectrally weighted irradiance for human melanopic photopigments

Fig. 11 Results for LED retrofit bulb with radiation spectrum, corresponding to CCT 5744K

Conclusions







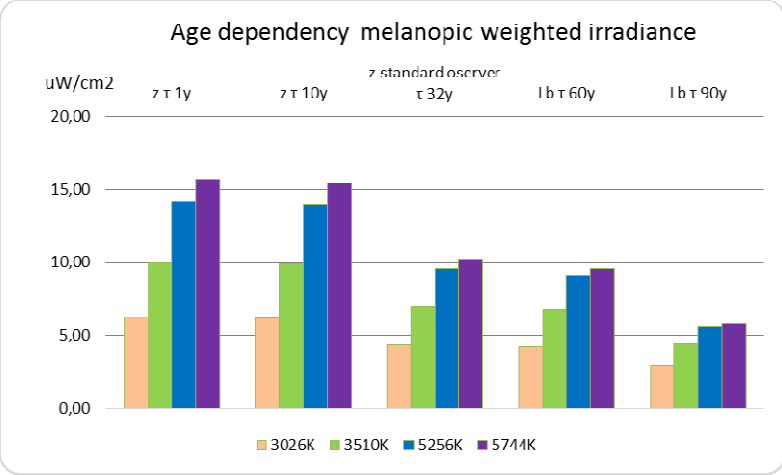


Fig. 12 Influence of age related transmission of ocular media and spectral distribution of different LED light sources on the quantitative determination of blue light hazard and the melanopic weighted irradiance

Conclusions

Younger people are more sensitive, both in terms of the retinal damage due to the presence of radiation in the blue-violet part of the spectrum, and the melanopsin reactions by radiation in the blue-turquoise part of the spectrum.

Blue light hazard	Melanopic irradiance
Maximal received quantities (1 year old child)	
58 to 68%	44-53% from determined for standard 32 year old observer
Minimal received quantities (90 year old observer)	
6 to 11%	44% less from determined for standard 32 year old observer

Conclusions

Blue light hazard

Age-related changes also lead to reducing differences in the effective values for the blue light radiance (assessed with the function of spectral sensitivity of the retina) in various sources.

Melanopic irradiance

There are no considerable differences in the effective radiation for the observers up to 60 year old compared with the standard one. They are up to 8% lower depending on the spectrum of the radiation sources.
After this age there is a significant drop.

Conclusions

To obtain a more precise estimation of the non-visual effects of optical radiation is useful to be reported all available data when calibrated measurements of the spectrum of radiation sources is performed. Defining of spectrally weighted biological quantities is appropriate to carry out not only for the specific lighting conditions but for known age groups of the observers.

THANK YOU
FOR THE ATTENTION !