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PHYSIOLOGICAL OPTICS

The effect of blue-light-blocking lenses on retinal straylight

Gatis Ikaunieks*, Inese Petrovica, Kristine Kalnica-Dorosenko and Gunta Krumina

Department of Optometry and Vision Science, Faculty of Physics, Mathematics and Optometry, University of Latvia, Jelgavas iela 1, LV-1004, Riga, Latvia

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Abstract. Sometimes yellow-tinted lenses are recommended to help improve visual quality. As yellow lenses filter blue light, it is believed that their use could decrease the intensity of scattered light in the eye (retinal straylight). However, the results of some studies have contradicted this assumption (Van Os et al. 2017). Currently various nontinted blue-light-blocking lenses are used to protect the eyes from short-wavelength light. The objective of this study was to determine whether blue-light-blocking lenses affect the levels of retinal straylight in the eye. A straylight meter (C-Quant, Oculus) was used for retinal straylight measurements. The measurements were performed under four different conditions: 1. without a spectacle lens in front of the eye, 2. with a plano lens without an antireflective (AR) coating, 3. with a lens with a blue-light-blocking coating, and 4. with a yellow-tinted lens without an AR coating. The study involved 37 subjects with a mean age of 22 ± 1.3 (*SD*) years. No significant differences in straylight parameters (s) ($p > 0.05$) were observed for measurements obtained without a lens in front of the eye ($\log[s] = 0.90 \pm 0.02$ [*SE*]), with the uncoated lens ($\log[s] = 0.92 \pm 0.02$) and with the lens with a blue-light-filtering coating ($\log[s] = 0.92 \pm 0.02$). Retinal straylight was significantly increased with the use of a yellow-tinted lens ($\log[s] = 0.96 \pm 0.02$) compared with no lens ($p < 0.001$). Neither yellow-tinted lenses nor nontinted blue-light-blocking lenses reduce the levels of retinal straylight in the eye.

Key words: spectacle lenses, retinal straylight, blue light.

1. INTRODUCTION

Retinal straylight is one of the main optical factors affecting drivers' vision quality. Increased levels of retinal straylight in the eye cause drivers to experience disability glare, which can be particularly problematic when driving at night (Van den Berg et al. 2009). Some researchers have suggested that yellow-tinted lenses can reduce disability glare (Hammond et al. 2009; Massof 2019). This hypothesis is often based on the assumption that the human eye is affected by Rayleigh-type light scattering, in which short-wavelength light is scattered more than medium- and long-wavelength lights. However, as strong Rayleigh-type light scattering has been observed in young people with highly pigmented eyes, this assumption is only partly accurate. Conversely, light scattering at all wavelengths in elderly people is similar (Coppens et al. 2006a; Ginis et al. 2013).

Studies have produced contradictory results on the effects of yellow-tinted lenses on vision quality. Some have reported improvements in vision with such lenses. Lacherez et al. (2013) recorded and compared the response times of young and older adults to traffic hazards in video presentations by using both yellow and neutral density filters. When the participants wore yellow filters, the younger participants' responses to hazards were much quicker than those of the older subjects. Hammond et al. (2009) investigated whether implanting yellow intraocular lenses (IOLs) could provide visual benefits in terms of glare disability and photostress

* Corresponding author, gatisik@lu.lv

recovery. They used the grating stimulus in a veiling glare experiment, and the intensity of a broad-band glare source (xenon annulus) was adjusted until the grating stimulus was no longer visible. The results revealed that subjects with yellow IOLs could withstand considerably brighter light than subjects with clear IOLs. In Rabin and Wiley's (1996) study, yellow lenses were confirmed to increase the apparent contrast and brightness of objects. Conversely, the results of other research (Silica et al. 2010; Eperjesi and Agelis 2011) showed no improvement in visual acuity and contrast sensitivity with yellow-tinted lenses.

According to Mainster and Turner (2012), coloured lenses cannot decrease disability glare in common situations in which the spectra of the target and glare light sources are similar; this is because they decrease the target and glare illumination in the same proportion. The aforesaid is confirmed by Van Os et al. (2017), who have revealed that retinal straylight, which is the main cause of disability glare, is not reduced by the use of yellow-tinted lenses (Van den Berg et al. 2009). In their study, the levels of retinal straylight were slightly higher with yellow-tinted lenses than with clear lenses. Cerviño et al. (2008a) obtained similar results with their study into the effects of yellow and clear contact lenses. It is possible that the increase in retinal straylight with tinted lenses is attributed to the pigment particles in coloured lenses, which could cause a diffraction effect of the incident light (Van Os et al. 2017).

Today, blue-light-blocking lenses are recommended for protecting the eyes from short-wavelength light. Some are nontinted with antireflective (AR) interference coatings that selectively reduce the transmission of blue light (at a cutoff wavelength of up to 495 nm). Although this type of lens transmits less blue light than yellow-tinted types, it has a higher overall light transmission capability (Giannos et al. 2019). The absence of yellow pigment in these lenses might decrease light scattering in the lens.

Additionally, some studies have suggested that short-wavelength-blocking lenses reduce the symptoms of eye fatigue during screen work (Lin et al. 2017). However, other researchers have highlighted the absence of high-quality evidence to support the use of blue-light-blocking lenses for improving both visual performance and retinal health (Lawrenson et al. 2017). Research into the effects of blue-light-blocking lenses on vision is ongoing, and their impacts on retinal straylight are as yet unknown.

The objective of this study was to assess whether blue-light-blocking lenses affect the levels of retinal straylight in the eye. The amount of retinal straylight with blue-light-blocking lenses was hypothesized to be comparable with that of clear spectacle lenses with a cutoff wavelength of ≤400 nm.

2. METHODS

2.1. Subjects

A total of 37 young adults (3 men and 34 women with a mean age of 22 ± 1.3 [*SD*] years) with no ocular diseases participated in this research. The spherical equivalent refraction for participants was between −7.00 and +2.00 D. No refractive correction was required for the straylight measurements (Franssen et al. 2007). As straylight values are not significantly increased when using soft contact lenses (Van der Meulen et al. 2010), wearers of such lenses were permitted to perform the measurements while wearing their lenses. Subjects with corrective spectacles performed the measurements without their glasses.

Written consent was obtained from each participant before the study. Ethical approval was given by the Ethical Committee of the Institute of Cardiology and Regenerative Medicine at the University of Latvia.

2.2. Device and method

Retinal straylight levels were measured by means of a C-Quant straylight metre (Oculus). This instrument uses a compensation comparison method, which is described in detail by Franssen et al. (2006). The compensation comparison method has good agreement with the objective measurements of retinal straylight (Van den Berg et al. 2009). The standard deviation (*SD*) of the repeated measures of the straylight parameter (s) for the C-Quant straylight metre was between 0.04 and 0.13 log units (Cerviño et al. 2008b).

The compensation comparison method is based on the direct compensation method (Van Den Berg 1986). The direct compensation method involves presenting a flickering (~8 Hz) stimulus with a concentric annulus and a central test field (Fig. 1).

During measurement, the subject was asked to fixate on the test field. Light scattering in the eye caused some of the flickering light from the annulus to reach the test field, and the subject perceived a flicker in the centre of the annulus. To determine the precise amount of straylight, a variable counterphase compensation light was presented in the test field. The perceived flicker in the test field could be eliminated by adjusting the levels of compensation light. The measurement of retinal straylight in the direct compensation method was in accordance with the standards established by the Commission International d'Eclairage (Vos 1984). On the basis of this, the retinal straylight levels could be calculated from Eq. (1) as follows:

$$s = \frac{\theta^2 L}{E}, \tag{1}$$

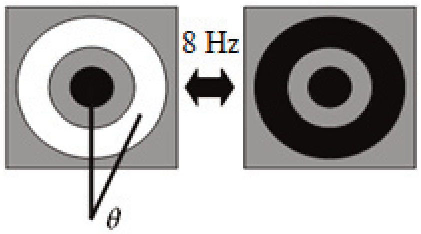

Fig. 1. A stimulus in the direct compensation method. The stimulus consists of a flickering annulus. The left image shows the on-phase (white annulus), and the right image shows the off-phase. The test field is in the centre of the ring (the dark circle). θ denotes the angular distance of the glare source from the fixation point.

where L is the luminance (cd/m^2) of the test stimulus (the luminance of the counterphase compensation light), E refers to the illuminance (lux) at the pupil plane caused by a straylight source (the annulus), and θ denotes the angular distance in degrees between the line of sight and the straylight source (Fig. 1).

In the compensation comparison method, the test area is divided vertically into two half-circles with and without the compensation light. Then, in a forced choice paradigm, the subject selects the half that flickers the most (Franssen et al. 2006).

2.3. Ophthalmic lenses

The decimal logarithm of the straylight parameter (s) (log[s]) was estimated under four different conditions: 1. without a spectacle lens in front of the eye, 2. with a plano lens without an AR coating, 3. with a lens with a blue-light-blocking coating, and 4. with a yellow lens without an AR coating (at a cutoff wavelength of ~450 nm). The yellow lens was produced by submerging a clear lens into a bath of liquid yellow dye. All lenses were made of CR-39 plastic polymer and had a refractive index of 1.50. There were no visible scratches on the lenses, and they were cleaned with a clean microfibre cloth prior to the measurements.

During the measurements, the lens was placed in the special lens holder of the C-Quant straylight metre. The distance between the eye and lens was ~20 mm. The measurements with spectacle lenses were obtained in random order for all participants. At least three measurements were taken for each lens, and measurements without lenses were also obtained. Measurements with an estimated $SD > 0.08$ or a quality parameter < 0.5 were rejected and repeated.

All measurements were taken in a dim room (~9 lux, Konica Minolta Illuminance Meter T-10). The dominant eye was used for the measurements, and the other eye was covered with an eyepatch. Figure 2 presents the spectral transmittances of the lenses, which were obtained by means of an Ocean Optics USB4000 spectrometer.

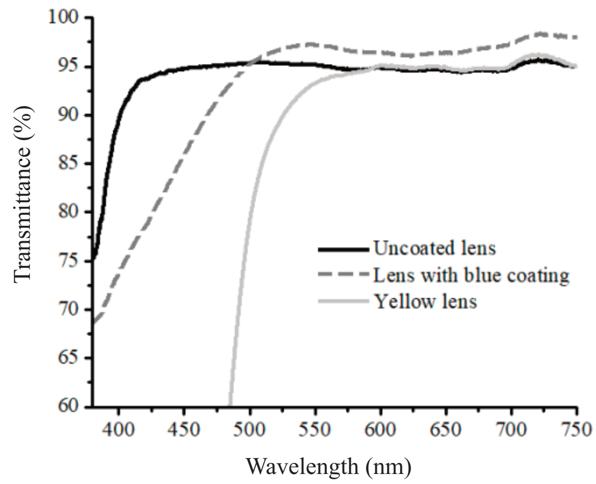

Fig. 2. Spectral transmittances of the clear uncoated lens, the clear lens with a blue-light-filtering coating, and the uncoated yellow lens.

2.4. Statistical analysis

Program G*Power 3.1.9.7 (Faul et al. 2007) was applied to determine the appropriate sample size. To find a difference of 0.05 log units with an SD of 0.08 log units (Coppens et al. 2006b) at the two-sided $\alpha = 0.05$ level, a population of 36 subjects was required.

The Kolmogorov–Smirnov test of normality (socscistatistics.com) was used to determine the distribution of data groups. Average values between the data groups were compared using a one-tailed dependent samples t-test. An extra-sum-of-squares F-test was implemented to compare the slope of the regression line with a hypothetical value. A significance level of 0.05 was utilized for the statistical analysis, and all data were processed with the help of MS Excel.

3. RESULTS

Figure 3 shows the mean log(s) values obtained under different conditions. As the data in each group exhibited a normal distribution (the Kolmogorov–Smirnov test of normality), a one-tailed paired t-test was implemented to compare the mean straylight values. There were no significant differences in retinal straylight between the measurements obtained with ($M = 0.92$, $SD = 0.13$) and without the uncoated colourless lens ($M = 0.90$, $SD = 0.14$), $t(36) = 1.12$, $p > 0.05$.

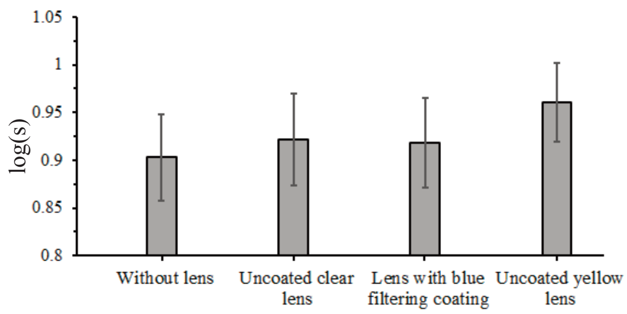

Fig. 3. Mean log(s) values of all participants measured without the lens in front of the eye, with the clear lens, with the blue-light-filtering lens, and with the yellow lens (the confidence interval [2 standard errors] is shown for each data series).

The straylight values obtained with the blue-light-filtering coated lens ($M = 0.92$, $SD = 0.14$) were not statistically different from those obtained for the uncoated clear lens ($M = 0.92$, $SD = 0.13$), $t(36) = 0.23$, $p > 0.05$.

The yellow lens produced a significantly higher mean straylight log(s) ($M = 0.96$, $SD = 0.11$) than both the uncoated clear lens ($t[36] = 3.26$, $p \leq 0.001$) and the blue-light-filtering coated lens ($t[36] = 3.28$, $p < 0.001$).

The relation between the log(s) values measured with the clear and yellow lenses is presented in Fig. 4. Pearson's correlation coefficient was $r = 0.82$, and the slope of the regression equation was 0.72.

If the increase in retinal straylight with the yellow lens compared with the nontinted lens is indeed related to

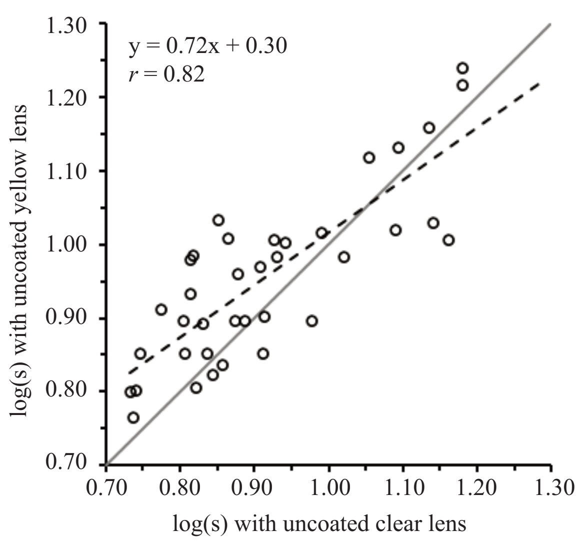

Fig. 4. The relation between the log(s) values measured with clear and yellow lenses. The dashed line is the regression line, and the solid line represents perfect agreement (along with the regression equation and Pearson's correlation coefficient).

colour pigments, an equal increase in scatter for all subjects would be anticipated. Furthermore, the linear regression line slope (x) (shown in Fig. 4) would not differ significantly from 1. Here, the slope was 0.71, which is significantly < 1, $F(1, 35) = 10.19$, $p < 0.01$.

4. DISCUSSION

The retinal straylight values obtained without a lens had a mean value of log(s) = 0.90 ± 0.14 (*SD*), which is close to the normal value (log[s] = 0.86 ± 0.2) of the subjects' mean age (21.6 years) (Van Den Berg et al. 2007). Some subjects recorded higher retinal straylight values than the upper limit of the age range (log[s] = 1.06). Similar results for retinal straylight values significantly above the age norm (Rozema et al. 2010) have been reported in other studies.

There were similarities in the levels of retinal straylight measured without a lens and with a tinted lens ($p > 0.05$). This is in accordance with the findings of De Wit and Coppens' (2003) research, which has revealed that clean colourless spectacle lenses produce an insignificant increase in retinal straylight.

The average increase in retinal straylight with the yellow-tinted lens compared with the clear lens (Δlog[s] = 0.04) was close to the results (Δlog[s] = 0.07) obtained by Van Os et al. (2017). For a perceivable difference in vision quality, an increase of at least 0.1 log units in retinal straylight parameter (s) is required (De Wit et al. 2006). Therefore, the increase in retinal straylight obtained by using the yellow lens is not considered clinically relevant.

As the slope of the regression equation was significantly different from 1, the results do not support the hypothesis that the increase in retinal straylight with yellow lenses is due to the colour pigment contained in the lens. Van Os et al. (2017) also tested this hypothesis by measuring retinal straylight with two yellow lenses placed in front of the eye. In that case, there was no significant increase in retinal straylight levels obtained using two lenses over those obtained from a single yellow lens. Therefore, the results of Van Os et al. (2017) do not support the assumption that the colour pigment in the yellow lens significantly increases retinal straylight in the eye.

To date, the effect of retinal illumination when viewed through tinted lenses remains untested for measurements of retinal straylight. The objective measurement of retinal straylight (Ginis et al. 2012) could help clarify the mechanism of straylight increase when using yellow lenses.

The results of this study confirmed that retinal straylight levels in the eye were not reduced by the use of a nontinted blue-light-blocking lens. This finding corroborates the results of Mainster and Turner (2012) who reported that retinal straylight cannot be reduced using spectacle lenses.

As other research (Lacherez et al. 2013) has revealed different effects of yellow lenses on the visual functions of different-aged subjects, future research should apply the method to a group of older subjects. Furthermore, the standardization of methods for evaluating the spectral transmission properties of lenses would facilitate better comparisons between the results of different studies.

5. CONCLUSIONS

This study has confirmed that retinal straylight in the eye cannot be reduced by the use of yellow-tinted lenses or nontinted blue-light-blocking lenses. Therefore, it is concluded that possible improvements in vision function with blue-light-blocking or yellow lenses are not associated with changes in retinal straylight but are linked instead to other factors, including increases in apparent contrast and brightness (Rabin and Wiley 1996).

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Sinist valgust blokeerivate läätsede mõju võrkkesta hajusvalgusele

Gatis Ikaunieks, Inese Petrovica, Kristine Kalnica-Dorosenko ja Gunta Krumina

Vahel soovitatakse nägemise kvaliteedi parandamiseks kollase tooniga läätsi. Kuna need filtreerivad sinist valgust, siis usutakse, et nende kasutamine võib vähendada hajusa valguse intensiivsust silmas (võrkkesta hajusvalgust). Samas on varasemate uuringute tulemused olnud selle väitega vastuolus (Van Os et al. 2017). Praegusel ajal kasutatakse mitmeid toonimata sinist valgust blokeerivaid läätsi, kaitsmaks silmi lühikese lainepikkusega valguse eest. Selliste läätsede mõju nägemisele on veel uurimisel ja uuringute tulemused seoses võrkkesta hajusvalguse hulga kohta on avaldamata. Käesoleva uuringu eesmärk on välja selgitada sinist valgust blokeerivate läätsede mõju võrkkesta hajusvalguse tasemele silmas.

Võrkkesta hajusvalguse mõõtmiseks kasutati vastavat mõõturit (C-Quant, Oculus). Mõõtmisi viidi läbi neljas erinevas tingimuses: 1) ilma prilliläätseta silma ees, 2) koos nulltugevusega ilma peegeldusvastase (AR) katteta läätsega, 3) sinist valgust blokeeriva kattega läätsega ja 4) kollase tooniga ilma peegeldusvastase katteta läätsega. Uuringus osales 37 täiskasvanut keskmises vanuses 22 ± 1,3 (*SD*) aastat.

Statistiliselt olulisi erinevusi hajusvalguse parameetrites ei leitud ilma prilliläätseta silma ees (log[s] = 0,90 ± 0,02 [*SE*]), ilma peegeldusvastase katteta (log[s] = 0,92 ± 0,02) ja sinist valgust blokeeriva kattega läätsede osas (log[s] = 0,92 ± 0,02). Võrkkesta hajusvalgus suurenes oluliselt kollaste prilliläätsede puhul (log[s] = 0,96 ± 0,02), võrrelduna ilma prilliläätseta silma ees ($p < 0,001$).

Võrkkesta hajusvalguse tase silmas ei vähenenud kollaste toonitud läätsede ega toonimata sinist valgust blokeerivate läätsedega.