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Does blue-violet filtering in contact or ophthalmic lenses improve contrast sensitivity?

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Summary. — The effects of blue-violet filtering lenses (yellow lenses) on visual performances and more specifically on contrast sensitivity (CS) are still debated in the literature. In this work, results obtained with contact lenses (CLs) and ophthalmic lenses (O_{ph}Ls) with different optical properties are compared and discussed. A negative statistically significant ($p < 0.05$) moderate correlation of the CS variation with different lenses as a function of the CS of the subject with the clearer one was observed. This means that filtering is expected to produce a CS worsening in subjects showing a relatively high initial CS. On the contrary, subjects showing a relatively low initial CS are expected to show a CS improvement.

1. – Introduction

Blue-violet light filtering ophthalmic, intraocular, and contact lenses (yellow lenses) have received increased attention in the last years [1-9]. As far as contrast sensitivity (CS) is concerned, the results reported in the literature depend on the specific spectral transmission properties of the investigated filters. There are more literature studies on ophthalmic lenses (O_{ph}Ls) than on contact lenses (CLs). Some authors reported neutral or negative effects of yellow O_{ph}Ls compared to clear ones. Other authors reported an improvement of visual performances when using yellow O_{ph}Ls both in healthy subjects and in patients affected by cataract, or retinal diseases. The results on CLs are few and, in some ways, conflicting [6-9]. The purpose of the present study is to characterize and compare the optical transmittance properties in the visible range of specific CLs and O_{ph}Ls and to investigate a possible dependence of the CS variation when changing the filter on the subjects' baseline CS measured with the clearer one of the two.

2. – Materials and methods

2·1. *Materials.* – Two types of Filcon IV hydrogel CLs (Mark'ennovy, Spain) were investigated. They are known as Xtensa (clear CL, sample A in this work, central thickness of a −3.00D CL equal to 100 μm) and Jade (yellow CL, sample B in this work, central thickness of a −3.00D CL equal to 90 μm). The O_{ph}Ls under investigation are a clear lens (Super Hi-Vision, Hoya, Japan, refractive index at the wavelength of the Fraunhofer D line equal to 1.592, Abbe number 41, sample C in this work), a light yellow lens (AR Drive Standard, Hoya, Japan, refractive index at the wavelength of the Fraunhofer D line equal to 1.592, Abbe number 40, sample D in this work), and a dark yellow one (AR Drive Professional, Hoya, Japan, refractive index at the wavelength of the Fraunhofer D line equal to 1.592, Abbe number 40, sample E in this work). Transmittance (T) spectra were measured by a Jasco V-650 spectrophotometer (JASCO Corporation, Japan) in the spectral range 380–780 nm, with spectral bandwidth equal to 2 nm. Preliminary repeated measurements were carried out on both ophthalmic and contact lenses to evaluate the random error of the results. The coefficient of variation (CoV, ratio between the standard deviation and the mean value calculated on the repeated measurements) was found to vary from 4% to 20% depending on the wavelength in the range 380–780 (average CoV 11%, std dev 5%). Figure 1 shows the absorbance spectra in the visible range (absorbance is defined as −log(T)).

2·2. *Participants.* – The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Milano-Bicocca (prot. Int. 0059770/17, classif. II.18, C.IPA unimib C.AOO: AMMU06, C. reg. prot.: RP01). Before being enrolled in the study, each subject expressed his/her informed consent and gave the researchers permission to collect and treat personal and optometric data. In the case of CLs, 41 subjects (27 females, 14 males) were recruited for the CS measurements with samples A and B. Their mean age was 41.1 years (standard deviation 16.4 years, minimum 20 years, maximum 66 years). The inclusion criteria were the absence of any known ocular pathology, having a monocular best corrected visual acuity of the dominant eye of at least 0.1 logMAR (logarithm of the minimum angle of resolution), having astigmatism lower than 0.50D, and being wearers of CLs. For astigmatic subjects (within the limits of the inclusion criteria), the mean spherical equivalent was calculated for each eye as the algebraic sum of the value of the sphere and half of the cylindrical value. In the case of O_{ph}Ls, 40 subjects (19 females, 21 males) were recruited for this work for the CS measurements with samples C, D, and E. Their mean age was 47.7 years (standard deviation 14.6 years, minimum 24 years, maximum 73 years). The inclusion criteria were the absence of any known ocular pathology, having a binocular best corrected visual acuity of at least 0.1 logMAR, having good binocular vision (no anomalies in ocular motility, heterophorias at distance and near and fusional reserves at distance within the limit of the expected values, no suppression, and a stereoscopic acuity of at least 60 arcsec), and being regular wearers of O_{ph}Ls.

2·3. *CS measurements.* – A and B CLs with the appropriate mean spherical equivalent were fitted in both eyes of each subject in random order (although only results for the dominant eye are here reported): half of the participants received the A CLs before the B CLs, whereas the other half received the reverse order. Ten minutes after CL insertion, the logarithm of the photopic CS (logCS) was measured monocularly on the dominant eye through a digital optotype system (Vision Chart, CSO, Florence, Italy) at a distance of 4.30 m ($\log CS_A$ and $\log CS_B$, for A and B CLs, respectively). In this work, only the results

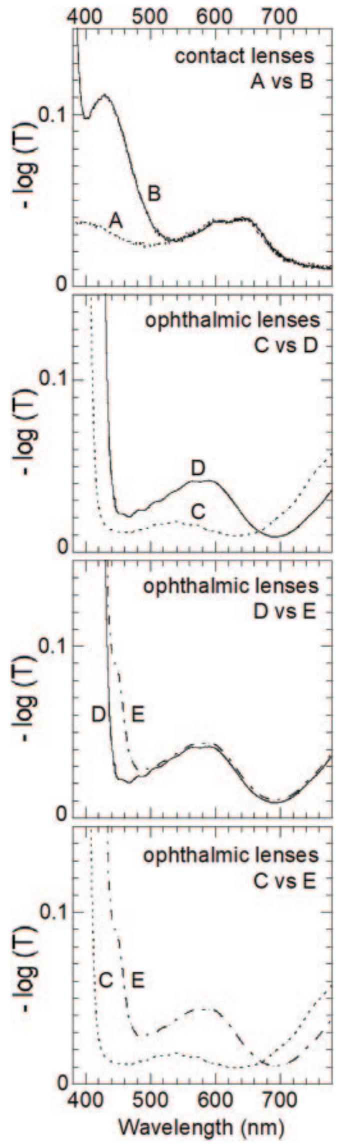

Fig. 1. – Absorbance ($-\log(\mathrm{T})$) spectra of the investigated CLs (A and B) and O_{ph}Ls (C, D, and E).

at the spatial frequency equal to 3 cycles per degree (cpd) are reported. In the O_{ph}L case, each participant received a pair of spectacles of the proper ophthalmic correction with clear lenses (sample C in this work) to wear for fifteen days. After fifteen days, 50% of participants received spectacles with the D lenses and the remaining participants received the E lenses. After fifteen days of wear, photopic CS measurements were carried out binocularly (with the dispensed glasses) through the Functional Acuity Contrast Test (FACT) at a distance of 3 m. After the CS measurement, the third type of glasses was delivered and, after fifteen days, the CS measurement was repeated with the third type of O_{ph}L.

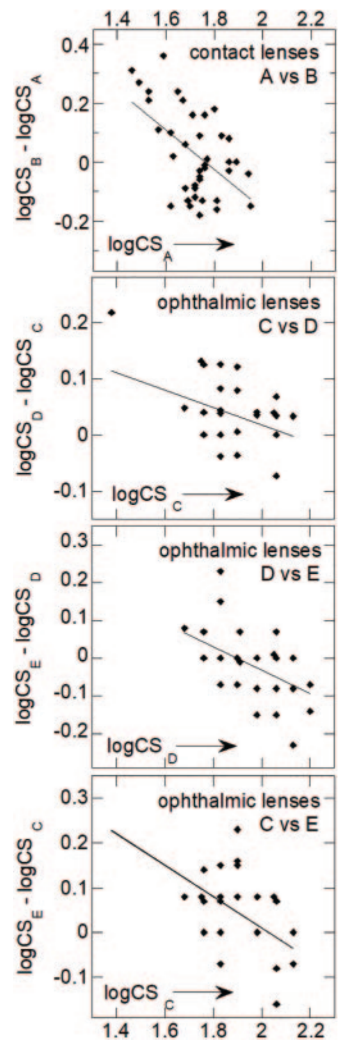

Fig. 2. – Difference between the logarithm of CS measured at the spatial frequency of 3 cpd on the same subjects with lenses B and A (or D and C, or E and D, or E and C) as a function of the value measured with A (or C, or D, or C). The continuous lines indicate the results of the linear regression of the data. The corresponding equations, in order from the first to the last panel, are: $y = 1.177 - 0.667x$, $R = -0.506$, p-value $= 0.0008$; $y = 0.327 - 0.154x$, $R = -0.378$, p-value $= 0.0177$; $y = 0.588 - 0.310x$, $R = -0.544$ p-value $= 0.0003$; $y = 0.711 - 0.350x$, $R = -0.508$, p-value $= 0.0010$, where x and y represent the abscissa and ordinate values, R is the Pearson correlation coefficient, and the p-value is the probability that the correlation between x and y in the sample data occurred by chance (all p-values being lower than the statistical threshold of 0.05).

Table I. – *Correlation coefficients obtained by Spearman's Rho test between the difference reported on the ordinate axis of fig. 2 and the variable on the abscissa axis at the spatial frequency of 3 cpd. The corresponding p-values are also reported.*

Comparison	Spearman's Rho	p-value
($\log CS_B - \log CS_A$) as a function of $\log CS_A$	0.80	< 0.01
($\log CS_D - \log CS_C$) as a function of $\log CS_C$	0.76	< 0.01
($\log CS_E - \log CS_D$) as a function of $\log CS_D$	0.57	< 0.01
($\log CS_E - \log CS_C$) as a function of $\log CS_C$	0.65	< 0.01

The data with the three lenses at the spatial frequency of 3 cpd are here indicated as $\log CS_C$, $\log CS_D$, and $\log CS_E$. The data measured with the three lenses are here indicated as LogCS_C, LogCS_D, and LogCS_E and were measured at 3 cpd.

The correlation between variables was studied by the Spearman's Rho test. The threshold of statistical significance was fixed at 0.05.

3. – Results and discussion

For each subject, the difference ($\log CS_B - \log CS_A$) between the CS data with the two CLs is reported in the first panel of fig. 2 as a function of the value obtained with the clear CL (sample A). The second, third, and forth panels of the same figure show the difference between the data with two ophthalmic lenses as a function of the value obtained with the clearer one of the two. Each panel of fig. 2 takes into consideration the same two lenses whose spectra are shown in the corresponding panel of fig. 1. As shown in fig. 2, subjects with a relatively low logCS on the abscissa axis typically show a positive value on the ordinate axis, highlighting a benefit provided by the second lens (the one different from the lens to which the abscissa axis refers). On the other hand, an opposite trend is observed for subjects who have a relatively high logCS on the abscissa axis. In this case, the difference is typically negative. The correlation coefficients, obtained by Spearman's Rho test between the difference reported on the ordinate axis of fig. 2 and the variable on the abscissa axis, indicate a relatively strong correlation, as reported in table I.

As far as the results obtained for CLs are concerned, a recent study reported a ceiling effect at 3 cpd, employing the same chart monitor with a high-definition liquid crystal display described in this study [10]. Although the ceiling effect cannot be excluded, this has not prevented the observation of the decreasing trend in fig. 2 and table I. This different behaviour between the subjects who had benefits and those who showed worsening conditions should be interpreted taking into consideration the optical properties of the lenses (fig. 1). The highest correlation coefficients were found for the comparison between the two CLs (A and B) and between the O_{ph}Ls C and D. The only difference in the visible range between A and B is the presence of the additional absorption band in the range 400–500 nm. Instead, the spectra of the C and D lenses show differences in a wider spectral range. The lowest correlation coefficient was found for the comparison between D and E lenses. In this case, the two spectra differ in blue with a relatively small difference in absorbance. As far as the interpretation of the results is concerned, the change of intraocular scattering is expected to play an important role in causing the CS differences observed between different filters and between different subjects [11]. Indeed, intraocular scatter has been described as the sum of different components, either wavelength-dependent straylight or additional straylight sources, which depend on eye pigment and age [12]. The combined contribution of each component, depending on individual characteristics, can result in either weak or strong wavelength dependency of the intraocular scatter. This could be responsible for the differences observed between filters and subjects.

4. – Conclusions

The CSs with CLs or O_{ph}Ls with different optical transmittance properties have been compared. The use of filters has been found to typically cause a CS improvement for subjects with a relatively low CS with the clearer lens and vice versa. When choosing the filter, practitioners should take into consideration that it can influence photopic CS, improving or worsening it for subjects who have a relatively low or high initial CS, respectively. The variation of intraocular scattering is expected to play an important role. It has been described as the sum of wavelength-dependent and wavelength-independent components. The combined contribution of each component (and thus the wavelength dependency of the intraocular scatter) may be different from subject to subject, thus causing the differences observed between the participants.

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