Original Article

Effects of color filters and anti-reflective coating on contrast sensitivity under glare condition

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Abstract

Background: Since light scattering has a great impact on visual performances, this study was conducted to compare the effects of color filters and anti-reflective coating on contrast sensitivity (CS) in normal people under glare condition.

Methods: This semi-experimental study was conducted on 40 medical students (aged 19-25 years). Ophthalmologic tests including visual acuity and refractive error measurement, biomicroscopy, fundoscopy, and CS assessment were conducted for all participants. CS was determined using Pelli-Robson chart at a distance of one meter. To measure the effect of glare on CS, we used an additional lighting source (60 W tungsten filament incandescent lamp) in the patient's visual field. Thus, at an intensity of 2000 lux, the light source was placed at a distance of 18.5 cm from the patient's eye in a way that it was 10 degrees above the subject's visual axis. Monocular CS measurements were performed with and without glare. Monocular CS was evaluated again under glare conditions with the yellow and pink filters, with the transmission rate of 85%, and anti-reflective coating.

Results: The mean log CS of subjects under glare (1.48 ± 0.09) was lower than that in the absence of glare (1.71 ± 0.09) (<0.001); moreover, repeated measures ANOVA showed the yellow filter (1.48 ± 0.10), pink filter (1.47 ± 0.10), and anti-reflective coating (1.47 ± 0.09) had no significant impact on improving visual performance under glare condition $(P = 0.471)$.

Conclusion: Colored filters and anti-reflective coatings are not effective in enhancing the vision of young normal individuals under glare conditions and at low spatial frequencies.

Introduction

Measuring contrast sensitivity (CS) in ordinary lighting conditions provides limited information about the decline of visual performance due to the exposure of eyes to light scattering in everyday life, including conditions such as driving at night.[1] In order to better understand the influence of light scattering on visual performance, it is helpful to calculate CS changes when an additional lighting source is put in the visual field.[2] Various studies have addressed the effect of glare on visual performance, and although the intensity of glare source varies in different studies, most of these reports agree on the decrease in visual acuity, particularly CS, under glare conditions.[2-4]

Meanwhile, there is evidence suggesting that the intensity of light scattering is inversely dependent on the wavelength of light, so that shorter wavelengths are more scattered and typically cause discomfort, glare, and reduction of CS and vision. Multiple solutions, including the use of colored filters, with the transmission rate of 85%, or anti-reflective coatings have been proposed to reduce

vision problems under various lighting circumstances.[3,5,6]

Different studies have been undertaken to investigate the effect of colored filters on enhancing the visual performance of people with glare disability. However, researchers have reached mixed and contradictory results because of variations in their method of measurement and the application of filters with different optical densities.[3,5,7] For example, whereas the corning photochromic filter has been proposed as the gold standard yellow filter to improve visual performance and rehabilitate people with low vision, Eperjesi and Agelis found a decline in vision and CS of normal young subjects under forward-light-scatter (FLS) conditions simulated by means of such filters.[5] In their research into the effect of yellow filters on visual acuity and CS of normal people in different age groups and under glare conditions, Mahjoob et al reported that these filters could only improve CS in older individuals with greater non-homogeneity in the ocular media; thus, their intervention had no positive impact on the visual performance of young subjects.[3] Many studies have also

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confirmed that short-wavelength absorbing filters (yellow filters or lenses with anti-reflective coating) may augment visual performance under glare conditions.[8-10] Many young and healthy people, despite their good visual acuity and CS, complain about significant visual impairment under glare conditions and in the presence of additional light in the visual field.[11,12] Therefore, it is imperative to explore different ways of alleviating glare disability and improving the visual performance of these individuals. The purpose of this study was to compare the effects of yellow and pink filters as well as anti-reflective coatings on CS of normal young people under glare condition.

Methods
Using G*power 3.1.9.2, total sample size of 40 participants seemed to be sufficient for within-participant's comparisons with power= 0.95, alpha= 0.05, effect size= 0.25, non-sphericity correlation= 1, and 5 repeated measurements (three filters and two light condition).

This is a semi-experimental study approved by the Ethics Committee of Zahedan University of Medical Sciences and performed on the students (aged 19-25 years) of that academic institution. Prior to ophthalmologic examinations, the purpose of the study and its procedure were explained and a written consent was obtained from all participants. All subjects were asked about their medical and ophthalmic history before taking the tests, which included visual acuity and refractive error measurement, slit lamp, fundoscopy, and CS assessment. The E chart was placed at a distance of 6 meters to evaluate participants' vision with and without refractive correction. Auto refractometer AR 8800 (Topcon, Tokyo, Japan) was used to carry out refraction for all subjects. The eligibility criteria included the absence of any ophthalmic pathology, opacity of the ocular media, and a 20/20 vision without correction. In other words, after refraction, subjects with +0.50 to -0.50 diopter sphere who had a 20/20 vision without correction were recruited.

Pelli-Robson chart was applied at a distance of one meter to evaluate CS. In order to adjust the ambient light intensity, we used a fluorescent lamp and a 50 W tungsten halogen lamp. The illumination of the chart surface and the patient's eye was 100 lux, which was measured using TES 1337 B photometer (TES Electrical Electronic Corp. Taiwan). Monocular CS was determined using Pelli-Robson chart at a distance of one meter. An additional lighting source (60 W tungsten filament incandescent lamp) was placed in the patient's visual field in order to measure the impact of glare on reducing CS. Specifically, at an intensity of 2000 lux, the lighting source was positioned at a distance of 18.5 cm from the patient's eye so that it was 10 degrees above the patient's visual axis. Next, monocular CS was evaluated again under glare conditions in order to specify the effect of yellow and pink filters and anti-reflective coatings in diminishing glare and heightening the visual performance of patients.

The transmission rate of yellow and pink filters was 85%. To confirm the transmission rate of the filters, we placed the lighting source in one end of a standard opaque black cylinder and installed a photometer (Hagner Universal Photometer, Model S3) at the other end; then, the intensity of the lighting source was determined. Afterward, yellow and pink filters were inserted between the lighting source and the photometer in order to re-measure the intensity of light. The transmission rate of filters was 85% in this state.

CS was measured for both the right and the left eye; however, given the logarithmic correlation of CS in the two eyes, the results are reported only for the right eye. Kolmogorov-Smirnov test was used to examine data normality. As data were normal, parametric tests were deployed to analyze the results. Repeated measures ANOVA was used to evaluate CS under different conditions. The results of pairwise comparison with Bonferroni correction were expressed as mean difference and 95% confidence interval of mean difference. Values below 0.05 were considered statistically significant.

Results
This research was performed on 40 patients, of whom 11 (27.5%) were male and 29 (73.95%) were female. The age of subjects ranged from 19 to 25 years, with a mean of 21.62 ± 1.58. Table 1 represents the mean and standard deviation of the log of CS under various lighting conditions with and without colored filters.

The results of repeated measures ANOVA supported the significant effect of glare on CS ($P < 0.001$). Table 2 shows the mean difference between log of CS under normal light condition and glare condition with and without colored filters. According to the table, the results of pairwise comparison with Bonferroni correction showed a decrease in CS under glare conditions as compared to normal lighting conditions.

Nevertheless, repeated measures ANOVA showed the colored filters and anti-reflective coating did not give rise to a significant improvement in the visual performance of subjects under glare conditions ($P = 0.471$).

Discussion
The results of this study suggested the decline in CS of normal young subjects under glare conditions - which is in keeping with previous studies - and also the failure

Table 1. The mean and standard deviation of the log of contrast sensitivity (CS) under various lighting conditions with and without colored filters.

Contrast sensitivity under various lighting conditions	Mean ± SD
CS without glare	1.71 ± 0.09
CS with glare	1.48 ± 0.09
CS with yellow filter under glare condition	1.48 ± 0.01
CS with pink filter under glare condition	1.47 ± 0.01
CS with anti-reflective filter under glare condition	1.47 ± 0.09

CS: contrast sensitivity; SD: standard deviation.

Table 2. The mean difference between log of contrast sensitivity under various light conditions with and without filter

Difference between various light conditions	Mean difference (95% CI)	P value
Normal light condition- glare condition with no filter	0.225 (0.180, 0.270)	0.000
Normal light condition- glare condition with yellow filter	0.221 (0.168, 0.274)	0.000
Normal light condition- glare condition with pink filter	0.236 (0.189, 0.284)	0.000
Normal light condition- glare condition with antireflex coating	0.232 (0.185, 0.280)	0.000
Glare condition without filter- glare condition with yellow filter	-0.004(-0.044, 0.037)	0.999
Glare condition without filter- glare condition with pink filter	0.011(-0.013, 0.036)	0.999
Glare condition without filter- glare condition with antireflex coating	0.007(- 0.031, 0.036)	0.999

CI: Confidence interval.

of yellow and pink filters and anti-reflective coatings to improve the visual performance of these individuals under glare conditions.

The additional light scattered in the visual field reduces the quality and CS of retinal images. Although more troubling in people with a history of refractive surgery, opacity or any non-homogeneity in the ocular media, glare disability and CS decline occur in normal individuals as well.[13]

No improvement was observed concerning the effect of yellow and pink filters on CS of subjects under glare conditions. Many studies have been done regarding the effect of colored filters on reinforcing visual performance, but the findings are occasionally inconsistent due to differences in measurement and evaluation of visual function on the one hand, and disparities in study populations and the use of different density filters on the other.[3,5,7,8,10,14] In their investigation into the effect of yellow filters on visual acuity and CS under glare conditions in healthy subjects of different age groups, Mahjoob et al found that these filters have a positive impact on CS in older adults alone and, similar to the present study, rejected the efficacy of these tools in young people.[3] It is well known that the intensity of light scattering depends on its wavelength. For example, shorter wavelengths (blue) are more scattered and, owing to the creation of glare, can result in lower visual acuity and CS.[15] Therefore, it is expected that utilizing short wavelength absorbing filters (yellow and pink) may improve people's visual performance as a result of reducing light scattering in the eye.[5] To the best of our knowledge, no study has so far addressed the effect of pink filters on CS under glare conditions. The effect of yellow filters on enhancing visual acuity and CS in patients with cataract and refractive surgery has been acknowledged in previous studies, but these filters have largely failed to bring about significant positive changes on CS.[7,14] Eperjesi and Agelis explored the effect of three filters with different densities on CS in healthy subjects who were exposed to FLS-simulated conditions and an additional lighting source. The authors did not observe a considerable CS improvement, though.[5] Also, in other study was found the yellow filter cannot significantly improve CS in LAZIK patients at the glare in photopic light condition.[7]

Our results indicated the inefficacy of anti-reflective coatings in improving CS under glare conditions. While most researchers have confirmed the impact of anti-reflective coatings in boosting the visual performance of people under glare conditions, there is still controversy regarding the effectiveness of these coatings in improving resolution and lowering glare intensity. Coupland et al. proposed that anti-reflective coatings could enhance CS by 1.5 to 5 times under glare circumstances.[16] The results of a study comparing the effect of eyeglass lenses with and without anti-reflective coatings on visual performance demonstrated that anti-reflective coatings could strengthen this performance through reducing glare and enhancing contrast, vision, and comfort.[6,9] Also, Mashige et al reported that the length of time it takes for a person in scotopic light condition to regain good vision after exposure to a glare source diminishes considerably by using anti-reflective coatings, thanks to their reduction of both reflectance and light scattering in the eye. Although it is claimed that anti-reflective coatings allow more light to reach the eyes and, consequently, make photoreceptors bleached. Mashige et al concluded that the influence of anti-reflective coatings on lowering light scattering - due to the decrease in reflectance - is more significant than their effect on increasing the amount of light entering the eyes.[6]

The incompatibility in the results of the present research and studies mentioned above may be due to differences in the CS test used and the spatial frequencies considered in each case. However, it should be noted that although the Pelli-Robson CS chart only examined spatial frequency of one cycle per degree, given the CS decline observed in the subjects exposed to glare conditions, it was expected that administering anti-reflective coatings would restore the desired CS, which did not happen. Considering the results of previous studies on the effectiveness of these coatings in improving CS and visual performance, and the fact that CS reduction rises at high-frequency conditions, it is promising to study larger sample sizes at the wider range of spatial frequencies. Furthermore, according to the results of our previous study,[3] which showed the greater effect of yellow filters on the reduction of glare in the older age group, and given the greater changes and eye problems in the elderly, it could be inferred that anti-reflective coatings will improve the visual performance of these individuals. Hence, one of the potential limitations

of our study was the limited age group of participants, and it is strongly recommended that future researchers investigate the role of such filters in eliminating the effect of glare in the elderly population over a wide range of spatial frequencies.

Conclusion

Overall, the results of the present study displayed that colored filters (yellow and pink) could not improve CS and visual performance of normal young subjects under glare conditions; therefore, it is not effective enough to administer these devices to be applied by these people when, say, driving at night. Whereas our results indicated the inefficacy of anti-reflective coatings in improving CS, given the mixed and contradictory findings of previous studies in this area, further study with higher sample size and higher age groups need to be undertaken to assess their effectiveness at different spatial frequencies.

Conflict of Interest

No conflicting relationship exists for any author.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of Zahedan University of Medical Sciences (Ethic code: IR.ZAUMS. REC.1398.450). Informed written consent was obtained from all patients prior to their enrollment in this study.

Authors' contribution

All the authors have contributed sufficiently in the intellectual content, conception and design of this work.

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