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# The effect of anti-reflection coating on glare threshold and recovery under scotopic conditions

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## Abstract

The purpose of this study was to determine the role of anti-reflection coating (ARC) in reducing the glare experienced during scotopic conditions. The effects were assessed using a Night Sight Meter. Thresholds were determined first by measuring the ability of the subjects to see under scotopic conditions and in the presence of a glare stimulus. The thresholds and glare recovery times with CR39 and Transitions lenses™ with and without anti-reflection coatings (ARC) were measured and compared for 37 subjects with 6/6 unaided visual acuities or better aged 18 to 30 years old (mean = 19.25 years ± 1.50). Glare recovery time was subsequently determined. Glare recovery times with coatings were compared. Night vision thresholds for CR39 lenses coated with ARC were lower (range = 29 cd/m$^2$ to 38 cd/m$^2$ pt, mean = 33.67 cd/m$^2$ ± 2.60) than that of CR39 without coatings (range = 27 cd/m$^2$ to 38 cd/m$^2$, mean = 34.24 cd/m$^2$ ± 2.82). The night threshold values for coated Transitions lenses were lower (range = 28 cd/m$^2$ to 40 cd/m$^2$, mean = 34.01 cd/m$^2$ ± 2.73) than for uncoated Transitions (range = 29 cd/m$^2$ to 42 cd/m$^2$, mean = 35.07 cd/m$^2$ ± 2.75). The difference was however statistically insignificant ($p > 0.05$). Also, the glare thresholds for CR39 lenses coated with ARC were lower (range = 40 cd/m$^2$ to 65 cd/m$^2$, mean = 50.20 cd/m$^2$ ± 6.06) than that of CR39 without coatings (range = 42 cd/m$^2$ to 70 cd/m$^2$, mean = 52.02 cd/m$^2$ ± 7.21). The glare threshold values for coated Transitions lenses were lower (range = 35 cd/m$^2$ to 70 cd/m$^2$, mean = 50.90 cd/m$^2$ ± 6.92) than for uncoated Transitions (range = 42 cd/m$^2$ to 80 cd/m$^2$, mean = 54.55 cd/m$^2$ ± 7.10). The glare recovery times for CR39 lenses coated with ARC (range = 1 s to 8.3 s, mean = 3.26 s ± 1.86) and Transition coated with ARC (range = 1 s to 10.9 s, mean = 3.52 s ± 2.23) were significantly lower compared to the times for similar lenses without coatings (range = 1.3 s to 11.9 s, mean = 4.65 s ± 2.20 for CR39 and range = 1.8 s to 16 s, mean = 4.94 s ± 2.85 for Transitions) ($p < 0.05$). Glare recovery times for coated CR39 lenses (range = 1 s to 8.3 s, mean = 3.26 s ± 1.86) and coated Transitions (range = 1 s to 10.9 s, mean = 3.52 s ± 2.23) were lower compared to times without lenses in front of the eye (range = 1 s to 15.1 s, mean = 4.04 s ± 3.21). These findings suggest that anti-reflection coating plays a significant role in reducing the effects of glare.

**Key words:** Anti-reflection coating (ARC), Glare recovery time, Glare threshold, Night Sight Meter, Transitions, CR39.

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## Introduction

Light is the stimulus for vision[1], however, when the brightness of the stimulus exceeds the normal threshold of brightness to which the photoreceptors are adapted, glare results. Glare can be defined as the reduction or disruption in visual performance, mainly visual resolution and comfort[1]. Glare can lead to blinding effects and can dangerously decrease visibility, for example with the bright head-lights of an oncoming car. With the advent of new technologies in car head-lights, drivers may be exposed to greater glare than with conventional tungsten halogen head-lights. These may lead to drivers experiencing problems with the eyes' ability to recover their sensitivity to see after being exposed to glare (visual re-adaptation)[2]. Traditionally, glare is classified into three types, namely, disability/veiling, discomfort and reflection glare, based on the source and type of visual degradation each causes[1, 2]. During scotopic (night) conditions the most common type of glare experienced is disability glare[2]. This occurs because the eye is not a perfect optical system and therefore does not produce a point-to-point image on the retina[2, 3]. Instead it obeys Rayleigh's law $(1/\lambda_4)$ in which nonhomogeneities in the eye scatter light across the retina and onto the retinal image. The scattering of light is greater for short wavelength than for long wavelength. There is a reduction in visual acuity (VA) and vision is restricted both during and after light exposure to glare[2, 3].

The visual system is affected in two ways, namely, differential threshold is raised due to reduction of VA from scattering of light and a veil of light is caused over the fovea which changes its adaptation or sensitivity to visual stimuli[2, 3]. Risk factors for glare include pathologies such as corneal oedema, vitreous opacities, albinism, cataracts and advanced age[4]. Older people for example, exhibit much less pupil reaction to light intensity levels and have increased risk of opacities in the ocular media which increase their susceptibility to glare. Schieber[5] found that glare recovery time assessments collected on young, middle aged and older adults showed that older subjects required three times longer to recover from glare. A comparative study of glare recovery times in myopes and emmetropes showed that myopes had a longer glare recovery time and were more susceptible to glare than emmetropes[6]. This difference was attributed to optical, retinal and non retinal factors[6]. The effects of ageing upon the recovery of contrast discrimination following exposure to a bright source of light showed that contrast thresholds to a small spot target increased gradually with age while total glare recovery times were constant up to 56 years, after which it was significantly prolonged[7]. Alcohol and marijuana have been found to produce delayed recovery of light adaptation following intense light exposure for at least 2 hours after ingestion[8].

Lenses coated with yellow tints ("night driving lenses") have been known to reduce the VA because of their low overall transmission[9]. These lenses when used for driving at night have been shown to increase glare recovery time[9]. Therefore their glare reducing effect is generally discredited as they cut out half of the spectrum visible by scotopic detection[9]. Columbia Resin 39 (PPG Industries, USA) plastic is made by polymerization of the diethyleneglycol allyl acid carbonate giving allyl diglycol carbonate (ADC). The monomer is an allyl resin containing two functional groups: ($CH_2.CH=CH_2$ and CH.OH)[10]. The main properties of ADC include transmittance of 89-92% and specific weight of 1.32 $g/cm^3$ at $25^0$ C. In addition, CR39 photopolymer is a high grade optical plastic with a refractive index is 1.498. CR39 is a transparent, thermosetting resin which combines an exceptional range of qualities which are not available in other plastic transparent materials[10, 11]. The CR39 plastic sheets are colourless and completely transparent to the visible light and also to completely opaque in infrared and ultraviolet region of the spectrum[10]. Other advantages of CR39 includes high abrasion resistance, resistance to heat distortion up to $100^0$ C and small hot flying particles such as welding sparks[10-12]. For these reasons, it is largely used for the production of tinted lenses and eye protection goggles[12].

Transition lenses are plastic lenses with an ultraviolet and scratch resistant coating, a photochromic tint that darkens in sunlight and has exceptional clarity indoors.[13] It is an ultra light plastic lens available in colours of brown and grey[13]. The speed at which the Transition lens reacts to light is usually used as a major indicator of the performance from regular lenses. It is exceptionally clear indoors that patients may not notice the difference from a regular uncoated lens[13, 14].

When a ray of light moves from one medium to another, of different refractive indices, some portion of light is reflected from the interface. The simplest method of reducing reflections involves the application of a thin layer of material at the interface, with a refractive index between those of the two media. Surface reflections become minimized when $n_1 = \sqrt{n_0 n_s}$, where $n_1$ is the index of the thin layer and $n_0$ and $n_s$ are the indices of the two media[10, 11]. The strength and actual amount of light reflected depends on factors such as colour, surface, angle of incidence and refractive index[15]. In the case of transparent substances, the percentage of light reflected for incident light that is normal or perpendicular to the surface may be calculated from Fresnel's Law of Reflection as: Percentage (%) reflected = $(n_0 – n_s / n_0 + n_s)^2$ x 100, where $n_0$ and $n_s$ are the refractive indices of the first and second media respectively[15].

Transition lenses transmit approximately 87% of visible light in the non-activated state increasing to about 94% when coated with an anti-reflection coating (ARC) thereby increasing the transmission[13-15]. Though there currently exist no standards for ARC on spectacles, the military (Mil-C-48497) has set certain standard tests for ARC on glass lenses[16]. These tests include the adhesion test, the abrasion tests, the ethanol test, the salt-water solution test as well as the temperature and humidity tests. The quality of ARC on CR39 lenses has been studied by Carlson[16] who reported good quality outcomes for overseas coated CR39 lenses compared to locally coated CR39 lenses in the tests performed. The transmission and reflectance characteristics of both samples of plano power plastic lenses coated with ARC to test for the consistency of ARC were however very similar as shown in Table 1.

The purpose of ARC is to reduce disturbing reflected images in the wearer's eyes[11, 13]. It is more suited for a lens of high refractive index because it reflects more light than a lens of lower index[13]. ARC works on the principles of wave interference, which utilises the fact that light travels as a wave. If the wave reflections from the front and the back of a coating layer are 180 degrees out of phase with each other they will cancel each other out and there will be no visible reflections[13-15] . This can be achieved if the reflection from the back of the coating travels half a wavelength further than that of the front. This occurs if the coating is a quarter of the wavelength thick. Because there is no net reflected energy the light actually continues through the lens. "Perfect coating" causes zero reflections for a specific wavelength and increased transmission of light. For perfect cancellation, two conditions must be met[15]. Firstly, the two wavelengths used must be exactly out of phase requiring that the thickness of the coating layer must be exactly ¼ of that wavelength (Quarter Wave Cancellation Theory)[15]. Secondly, the two waves need to be of equal intensity requiring that the two reflections are exactly out of phase. The purpose of this study was to estimate the rapidity with which vision recovers from the harsh effects of glare under the two tests conditions namely CR39 and Transitions lenses with and without ARC.

## Methodology

Night and glare thresholds as well as glare recovery times were measured in young volunteers (aged 18-30 years) wearing CR39 and Transition lenses with

**Table 1.** The average percentage (T%) of white light transmitted through each lens

| Manufacturer-Lens | Where ARC applied | %Transmittance |
|---|---|---|
| Uncoated CR39 | | 91.8 |
| Metal Lux-Computar | Local | 95.0 |
| Focus-Invisible | Local | 94.5 |
| General Optical-Saphire Diamond | Local | 97.0 |
| Sola Technologies-UTMC | Local | 96.5 |
| Hoya Hi-vision | Overseas | 96.7 |
| BBGR-Diamor | Overseas | 96.2 |
| Essilor-Crizal | Overseas | 96.8 |

Modified from Carlson, 2003

and without anti-reflection coating as well no lenses. The lenses were fitted onto large diameter plastic frames. All participants were chosen by convenience sampling and met a minimum uncompensated VA criterion of 6/6 or better monocularly. Volunteers with any form of ocular pathology were excluded from the study. All subjects included in the study reported having good health. They were instructed not to take alcohol or any intoxicating substance two days before the testing. The dominant eye of each subject was determined and tested first. Eye dominance was determined using the Miles test[17]. This was done by asking the subjects to extend both arms forward and bring both hands together to create a small triangle between thumb and the first knuckle. With both eyes open, the subjects were asked to look through the triangle and sight the door knob. The subjects alternated closing the eyes or slowly drew the opening back to the head to determine which eye is viewing the knob (i.e. the dominant eye)[17]. All experimental tests were conducted utilising a Night Sight Meter, model No. 3538 (see Figure 1), an instrument which simulates night driving conditions.

**Figure 1**: Night Sight Meter, Model 3835 (Quantum, USA)

The night sight meter measures the ability to see under scotopic conditions (night vision threshold) and in the presence of glare (glare vision threshold), as well as the time to recover normal vision after a glare stimulus has been removed (glare recovery time). The test target consisted of fifteen Landolt C's in four orientations, which were shown at a rate of 45 per minute. The Landolt C's passed through a diamond shaped opening in the upper left corner of the instrument thereby simulating night driving conditions through this continuous motion. The instrument was placed on a table 70 cm wide and the subject and examiner were seated on the opposite sides of the table. The testing room was set up in one of the Optometry clinics at the University of KwaZulu Natal. The room had no window or access to bright light. Target illumination in the night sight meter was provided by two 6 Watt 115 Volt lamps. The amount of light on the test target was controlled by a rheostat with grading from 0 to 100 cd/m$^2$. A light emitting diode digital display timer linked to a touch time stop switch was used to measure the glare recovery time. The glare assessment was preceded by five minutes of dark adaptation. The tests were performed monocularly using the dominant eye first, with the fellow eye occluded with an eye-patch and vice versa. The subject was reminded to keep his or her head against the eye shade and not look directly at the glare source but at the C's until all the tests were completed. To ensure and maximise subjects' co-operation and attention, a practice trial was performed with all the subjects where proper instructions were explained.

All the lenses (coated and uncoated CR39 and Transitions) used in the study were ordered from the same manufacturer. The lenses had plano power with a centre thickness of 2.5 mm and a diameter of 65 mm. The lenses were cleaned with Lensbrite (Peca Products, USA) to avoid increasing reflections during the procedure as lenses especially those coated with anti-reflection coating are extremely sensitive to finger prints, sweat and dust particles[16]. The following three tests were performed in this study: Night vision threshold, glare vision threshold and glare recovery times.

### *Night vision threshold*

This test was designed to assess the subject's ability to see in dim or low illumination. The target illumination was controlled by a rheostat with grading from a minimum of 0 to a maximum of 100. Night vision threshold was measured by instructing the subjects to look at the Landolt C and reporting the orientation of the openings in the C while the examiner moved the dial to decrease illumination by one unit at a time from 100. The end point was when the subject started incorrectly identifying the Landolt C or gave up. This procedure was done with CR39 and Transitions lenses with and without ARC as well as with no lens in front of the eye

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### *Glare vision threshold*

This test measures the subject's night vision threshold in the presence of a glare source. Glare vision threshold was determined by turning the glare light on and the subject calling out the orientation of the Landolt C whilst the dial was turned down by a unit at a time until the subject started missing the letters. The glare vision threshold value was recorded as the minimum amount of lighting required to detect and correctly identify the Landolt C orientation, with the glare source on. This procedure was done with CR39 and Transitions lenses with and without ARC as well as with no lens in front of the eye.

*Glare recovery time*

Glare recovery times were measured after exposure to a glare source for 10 seconds. This was done after setting the rheostat grating to the average of night vision threshold score obtained in the first test. The subject was reminded about the touch timer stop switch which was shown in the beginning of the test. At the end of the exposure period, the source was switched off and the timer started running automatically. The subject was instructed to report as soon as he or she could see the orientation of the Landolt C after the glare source has been removed (glare recovery times). At that point, the subject was asked to call out the orientation of the Landolt C's. The glare recovery time (seconds), was read off the digital display timer on the night sight meter and recorded.

Four readings were measured and the values averaged for each of the three tests. The procedure was repeated for the fellow eye. Night vision thresholds, glare thresholds and glare recovery times scores were categorized based on the values as specified by the manufacturers of the tester (Quantum, USA) (Table 2). Again this procedure was done with CR39 and Transitions lenses with and without ARC as well as with no lens in front of the eye.

## Results

*Night vision threshold*

Night vision threshold for the uncompensated eyes ranged from 27 cd/m$^2$ to 40 cd/m$^2$, with a mean of 33.76 cd/m$^2$ ± 2.70. For CR39 without ARC, night threshold ranged from 27 cd/m$^2$ to 38 cd/m$^2$, with a mean of 34.24 cd/m$^2$ ± 2.82. For Transitions without ARC, the night vision threshold values ranged from 29 cd/m$^2$ to 42 cd/m$^2$, mean = 35.07 cd/m$^2$ ± 2.75. (see Figure 2). The night vision threshold for uncoated Transitions was higher than of uncoated CR39 and the difference was statistically insignificant ($p = 0.998$). Night vision threshold for CR39 coated with ARC ranged from 29 cd/m$^2$ to 38 cd/m$^2$, with a mean of 33.67 cd/m$^2$ ± 2.60, while that of Transitions with ARC ranged from 28 cd/m$^2$ to 40 cd/m$^2$, mean = 34.01 cd/m$^2$ ± 2.73 . The difference between mean values of coated CR39 and transitions was statistically insignificant ($p = 0.971$). The mean value of night vision threshold for CR39 with ARC was 33.67 cd/m$^2$ ± 2.75 compared to a mean night vision threshold value of 34.24 cd/m$^2$ ± 2.82 for CR39 without coating. The mean night vision threshold value for coated transitions lenses was 34.01 cd/m$^2$ ± 2.73 while the mean for uncoated transitions was 35.07 cd/m$^2$ ± 2.75. The differences were not statistically significant ($p > 0.05$) for CR39 and Transitions respectively.

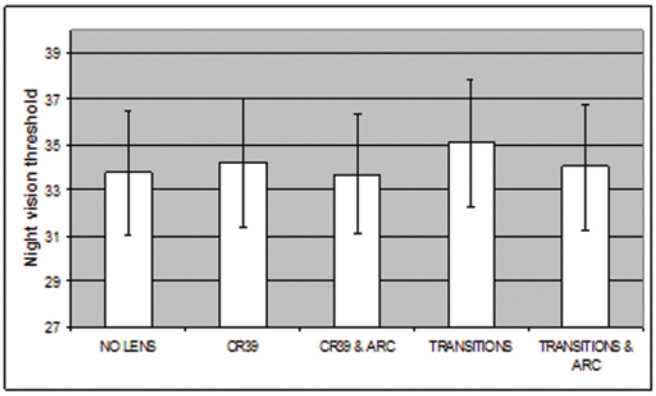

**Figure 2:** Night vision thresholds.

**Table 2**: Categorization of Night Sight Meter readings

| RATING | Night Vision Threshold (cd/m$^2$) | Glare Vision Threshold (cd/m$^2$) | Glare Recovery Time (secs) |
|---|---|---|---|
| A-GOOD | 0-15 | 0-30 | 0-1.5 |
| B-ABOVE | 16-20 | 31-40 | 1.6-2.5 |
| C-AVERAGE | 21-25 | 41-55 | 2.6-4 |
| D-BELOW AVERAGE | 26-35 | 56-76 | 4.1-6 |
| E-POOR | >35 | >77 | >6 |

Glare vision threshold for uncompensated eye ranged from 40 cd/m$^2$ to 65 cd/m$^2$, with a mean of 50.29 cd/m$^2$ ± 5.37. For CR39 without ARC, glare threshold ranged from 42 cd/m$^2$ to 70 cd/m$^2$, with a mean of 52.05 cd/m$^2$ ± 7.21. For Transitions without ARC, the glare vision threshold values ranged from 42 cd/m$^2$ to 80 cd/m$^2$, mean = 54.55 cd/m$^2$ ± 7.10 (see Figure 3). The glare vision threshold for uncoated Transitions was higher than of uncoated CR39 and the difference was statistically insignificant ($p = 0.081$). Glare vision threshold for CR39 coated with ARC ranged from 40 cd/m$^2$ to 65 cd/m$^2$, with a mean of 50.20 cd/m$^2$ ± 6.06 while that of Transitions with ARC ranged from 35 cd/m$^2$ to 70 cd/m$^2$, mean = 50.90 cd/m$^2$ ± 6.92. The difference between mean values of coated CR39 and Transitions was statistically insignificant ($p = 0.079$). Analysis of variance revealed that glare vision thresholds were significantly lower with CR39 and Transitions lenses coated with anti-reflection coating than both uncoated lenses ($p = 0.005$) (see Figure 3). The mean value of glare vision threshold for CR39 with ARC was 50.20 cd/m$^2$ ± 6.06 compared to a mean glare vision threshold value of 52.02 cd/m$^2$ ± 7.21 for CR39 without coating. The mean glare vision threshold value for coated transitions lenses was 50.90 cd/m$^2$ ± 6.92 while the mean for uncoated transitions was 54.55 cd/m$^2$ ± 7.10. The differences were highly statistically significant ($p < 0.05$) for CR39 and Transitions respectively.

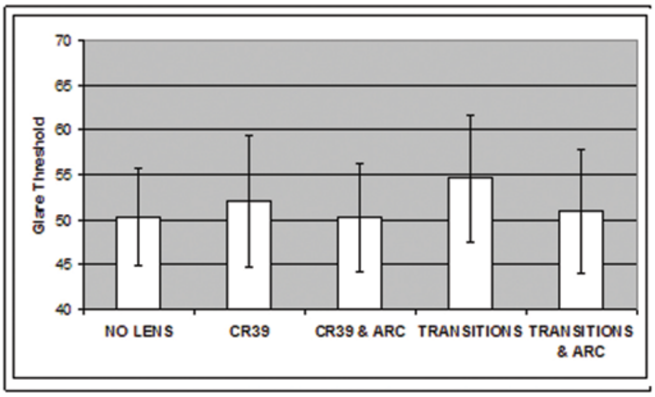

**Figure 3:** Glare vision thresholds of various lenses, with and without coatings.

The glare recovery times for the uncompensated eye (no lens) ranged from a value of 1 s to 15.1 s, mean = 4.04 s ± 3.21. The recovery times for CR39 without ARC ranged from 1.3 s to 11.9 s, with a mean of 4.65 s ± 2.20. For Transitions without ARC, the recovery times values ranged from 1.8 s to 16 s, mean of 4.94 s ± 2.85 (see Figure 4). The recovery times for uncoated Transitions were higher than for uncoated CR39 and uncompensated eye and these differences were not statistically significant ($p = 0.145$). The recovery times for CR39 coated with ARC ranged from 1 s to 8.3 s, with a mean of 3.26 s ± 1.86 while that of Transitions with ARC ranged from 1 s to 10.9 s, mean = 3.52 s ± 2.23. The recovery times for coated CR39 were lower or faster than that of coated transitions. However, this difference was not statistically significant. Analysis of variance revealed that mean glare recovery times were lower or faster with lenses coated with anti-reflection coating than those without a coating. The mean glare recovery time of CR39 coated with ARC was 3.26 s ± 1.86 and the mean for Transitions coated with ARC was 3.52 s ± 2.23 compared to a mean of 4.65 s ± 2.20 for uncoated CR39 and a mean of 4.94 s ± 2.85 for uncoated Transitions. The differences were highly statistically significant ($p < 0.05$) for CR39 and Transitions respectively. However, the glare recovery time of CR39 lenses coated with ARC (mean = 3.26 s ± 1.86) and Transitions lenses coated with ARC (mean = 3.52 s ± 2.23) was lower compared to no lenses in front of the subjects (mean = 4.04 s ± 3.21) as seen in Figure 4.

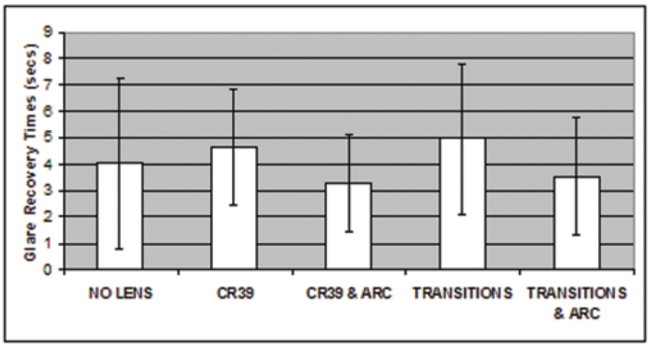

**Figure 4:** Glare recovery times of different lenses

## Discussion

The findings of this study indicate the potential benefits and value of anti-reflection coating in reducing the effects of glare. The anecdotal controversy and misconception surrounding the prescription of anti-reflection coating as just a commercial ploy with minimal or no effect on glare and resolution can be resolved in part by the results of this research. Night vision threshold measures the minimum amount of illumination that the subject required to see the test object in dim illumination, and the higher the night vision threshold, the poorer is the subject's night vision. All subjects had high night vision thresholds without lenses and with coated and uncoated CR39 and Transitions lenses that fell in the classification of below average. This implies that the subjects had poor ability to detect object under low illumination resulting in poor night vision with the uncompensated eye, uncoated and coated CR39 and Transitions lenses. A comparison of the mean night vision threshold for the uncompensated eye (33.76 cd/m$^2$ ± 2.70), uncoated CR39 (34.24 cd/m$^2$ ± 2.82) and Transitions (35.07 cd/m$^2$ ± 2.75) as well as coated CR39 (33.67 cd/m$^2$ ± 2.60) and Transitions (34.01 cd/m$^2$ ± 2.73) showed no significant difference. The poor night thresholds findings could be due to increased pupil size in dim illumination causing spherical aberrations.

Glare vision threshold measures the minimum amount of illumination required to detect the test target in the presence of glare under scotopic conditions. The higher the glare threshold value, the poorer is the subject's night vision in the presence of a glare source. The mean glare threshold values of the uncompensated eye, uncoated CR39 and Transitions lenses as well as coated CR39 and Transitions lenses fell in the classification of average to below average. This indicates that in the presence of glare, bleaching of the photoreceptors occur causing reduced sensitivity to light resulting in higher visual thresholds. Therefore glare creates noticeable problems during scotopic conditions.[1, 18, 19]

Glare thresholds increased significantly with the use of uncoated lenses in front of the eye compared to the standard i.e. no lens in front of the subjects (no lens vs uncoated CR39 ($p = 0.019$); no lens vs uncoated Transitions ($p = 0.0015$). This finding can be attributed to the introduction of a surface in front of the eye causing surface reflections that degrade the image quality resulting in higher thresholds in dim illumination. The significant glare vision threshold increase with Transitions lens compared to no lens in front of the eye is because of their low transmission values of 87% in the non-activated state as compared to CR39 which has a transmission value of 92%[13, 14]. A larger percentage of incident light is therefore lost to reflections in the Transition lens. When a comparison of mean glare vision thresholds between uncompensated eye (no lens) and coated lenses was made, no significant differences were found (no lens vs coated CR39 p = 0.889; no lens vs coated Transitions p = 0.483). However, coated CR39 (mean = 50.20 cd/m$^2$ ± 6.06) and coated Transitions (mean = 50.90 cd/m$^2$ ± 6.92) had significantly lower glare vision thresholds than their respective uncoated lenses (mean = 52.05 cd/m$^2$ ± 7.21) and (mean = 54.55 cd/m$^2$ ± 7.10). This implies better ability to see in the presence of glare under scotopic conditions for subjects wearing coated lenses compared to uncoated lenses. This finding can be explained by the fact that coating CR39 and Transition lens with ARC increases light transmission to 99.92% for CR39 and 94% for the Transition lens[14].

Glare recovery times assesses the minimum time needed to adjust to low levels of light illumination after a glare stimulus has been stopped. This gives an indication of subject's ability to recover vision after a glare source has passed and the shorter the recovery time, the faster the subject is able to recover good vision. For uncoated CR39 and Transitions, the mean glare recovery times fell in the classification of below average. Thus, the higher the glare recovery time, the slower it took the subject wearing uncoated lenses to recover good vision after exposure to a glare stimulus. When a comparison of recovery times was made between the uncompensated eye and uncoated lenses, no significant difference was found (no lens vs uncoated CR39 $p = 0.278$; no lens vs uncoated Transitions $p = 0.158$). However, mean glare recovery time was found to be significantly reduced from 4.65 s ± 2.20 to 3.26 s ± 1.86 when comparing uncoated CR39 lenses to coated CR39. Also, mean glare recovery time was found to be significantly reduced from 4.94 s ± 2.85 when Transitions were uncoated to 3.52 s ± 2.23 for Transitions coated with ARC. This could be due to the reduced reflections associated with ARC resulting in scattered light falling on the retina. The adaptive response governing photopigment regeneration is therefore hastened with the use of ARC, hence the reduced glare recovery times with lenses coated with an anti- reflection coating.

An interesting finding in this study is the decreased glare recovery times with lenses coated with anti-reflection coating and with no lenses in front of the eye compared to both uncoated lenses (see Figure 4). This result is most likely due to the fact that glare is caused by light of shorter wavelengths which the anti-reflection coating absorbs and the fact that lightly tinted lenses are useful in reducing the glare index[2, 3]. Statistical analysis supports the impression that the addition of anti-reflection coating to these two lenses significantly reduced glare (p<0.001). It has been argued by some authors[13, 14] that because of the higher light transmittance obtained with anti-reflection coating, more light is available to bleach the photoreceptors. However, it has been reported that the increased transmission of light is of less significance compared to its effect on light scatter due to reflectance[10, 11]. The need for reducing the effects of glare has been recognized by the congress of the United States of America, which made $1 000 000 available to conduct studies on the risks associated with glare to oncoming traffic and its effects on the driver's performance[18]. ARC can also be of great advantage when working in front of a computer monitor and during night driving where the effects of glare are harshest[20].

Night driving increases the risk of accidents as depth perception, colour and contrast are reduced significantly[21]. However, the ability to see under conditions of low illumination and against glare as well as glare recovery remains major concerns and important factors that affect night vision. The average glare recovery time is reported to be 5 to 7 seconds without any lens in front of the eyes[19]. The average person will travel approximately 0.40 kilometres with limited vision when driving at 96.5 km/h at night after experiencing glare[19]. Driving with ARC lenses at night is better than driving with lenses without ARC at all. Previous studies conducted show that subjects have reported benefits of ARC in their spectacle prescriptions which range from clearer, crispier and brighter general detail surroundings[22]. An assessment of the visual performance using the night sight meter revealed that the post-LASIK myopes had difficulty with night vision due to poor night and glare vision thresholds caused by higher aberrations and intraocular scatter from LASIK[23]. Glare recovery time however was not affected because the macula was still intact in LASIK patient. Glare recovery was found to be significantly prolonged in a group of patients with age related and pre-aged related maculopathies in comparison with the control group[24]. These showed that reduced visual performance and discomfort associated with glare recovery measurement is also sensitive indicator of functional integrity of the macula[24, 25].

## Conclusion

Night vision threshold appears to be reduced for the uncompensated eye as well as with both uncoated and coated lenses. Glare vision and recovery times reduced with the use of lenses coated with ARC under scotopic conditions. Continued prescription by optometrists and use of anti-reflection coating by patients are hereby recommended for night driving. It significantly reduces glare recovery times; shortening the period of discomfort and poor vision thus allowing safe and efficient driving conditions devoid of hazard and danger that can be caused by glare. Optometrists are encouraged to advise their patients on the need for drivers to use spectacles coated with anti reflection coating.

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## References

1. Ludt R. Three types of glare: Low Vision OMM Assessment and Remediation. *Review* 1997 **29** 1001-113.
2. Rubino M, Cruz A, Grcia JA, Hita E. Discomfort Glare indices: A comparative study. *Appl Optics* 1994 **33** 8001-8013.
3. Miller N. Glare is in the eye of the beholder. *Lighting Design & Application* 2001 **31** 36-41.
4. Brabyn JA, Haegerstrom-Portnoy G, Schneck E. Visual impairments in elderly people under everyday viewing conditions. *J Vis Impair & Blind* 2000 **94** 741-755.
5. Schieber F. Age and Glare Recovery Time for Low-Contrast Stimuli. *Human Factors and Ergonomics Society Annual Meeting Proceedings*, General Sessions pp 496-499.
6. Kurtev A, Given J. Glare recovery time in myopes. *Perception* 2004 33.
7. Collins M. The onset of prolonged glare recovery with age. *Ophthal Physiol Opt* 1989 **9** 368-371.
8. Adams AJ, Brown B, Haegerstrom-Portnoy G, Flom MC, Jones RT. Marijuana, alcohol and combined drug effects on the time course of glare recovery. *Psychopharmacol*. 1978 **56** 81-86.
9. Taylor SP. Vision and the older driver. *CE Optometry* 2002 **5** 41-72.
10. Jalie M. *The Principles of Ophthalmic Lenses,* The Association of Dispensing Opticians. 1980 pp 130-136.
11. Brookes C, Borish I. *System of Ophthalmic Dispensing.* NY: Fairchild Publications 1988.
12. Eskridge JB, Amos JF, Bartlett JD . *Clinical Procedures in Optometry.* New York: JB Lippincott, 1991 pp 114-159.
13. Young MJ. A.R Coating: A definition. *Optical World* 1988 **17** 8-12.
14. Wilkinson P. Lens Treatments. *Disp Optics* 2003 **18** 4-6.
15. Loshin DS. *Geometric Optics Workbook*. Butterworth and Heinemann, 1991 pp 21-42.

16. Carlson AS. A comparative study of anti-reflection coatings. *S Afr Optom* 2003 **62** 92-98.
17. Roth HL, Lora AN, Heilman KM. Effects of monocular viewing and eye dominance on spatial attention. *Brain* 2002 **125** 2023-35.
18. Olson PL, Aoki T. The measurement of dark adaptation level in the presence of glare. Ann Arbor 1989; MI: Transportation Research, University of Michigan. Report No.UMTRI-89-34.
19. Patorgis CJ. Photostress recovery testing. In: Eskridge JB, Amos JF, Bartlett JD. C*linical Procedures in Optometry*. Philadelphia: JB Lippincott Company, 1991 pp 482-486.
20. Charman WN. Vision and driving- a literature review and commentary. *Ophthal Physiol Opt* 1997 **17** 371-391.
21. Holladay JT, Dudeja DR, Chang J. Functional vision and corneal changes after laser in situ keratomileusis determined by contrast sensitivity, glare testing, and corneal topography. *J Cataract Refract Surg* 1999 **25** 663-669.
22. Keating MP. *Geometric, Physical and Visual Optics*, 2nd Ed. Boston: Butterworth Heinemann 2002.
23. Hansraj R. Night vision of the post-LASIK myope. *S Afr Optom* 2007 **66** 141-149.
24. Collins MJ, Brown B. Glare recovery and age related maculopathy. *Clin Vis Sci* 1989 **4** 145-153.
25. Stringham JM, Hammond BR. The Glare Hypothesis of Macular Pigment Function. *Optom Vis Sci* 2007 **84** 859-864.