# AR and non-AR lens performance during contrast sensitivity testing and daily activities

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## Abstract

Antireflective (AR) coatings are designed to reduce reflections and secondary images from the surfaces of spectacle lenses. They are often recommended for specific individuals or groups of individuals and also in particular daily or work environments. Much of the rationale behind prescribing these lenses is somewhat unsupported by published clinical studies. Previous research has compared the visual performance of AR versus non-AR lenses in a limited fashion using patient preference, acuity, glare, and contrast sensitivity testing. This study utilizes comparative data to determine not only if patients prefer AR lenses and in which environments, but also quantifies the benefit of AR as related to contrast sensitivity.

**Keywords:** antireflective coating, contrast sensitivity, visual acuity, visual comfort

## Introduction

The evolution of modern antireflective coatings can be traced back to Germany in the 1930s, but their application in ophthalmic lenses was not in evidence until nearly 20 years later[1]. Modern scientists continue to develop new technologies and produce antireflective coatings for both ophthalmic and other uses, as seen via research-based news reports[2,3]. As described by Fresnel's formula ($FR=[(n'-n)/(n'+n)]^2$) approximately 92% of incident light is transmitted by CR-39 lenses (n=1.498); 8% of the incident light, therefore, will be reflected back from the lens surfaces. Light reflectance is greater for polycarbonate (n=1.586) at approximately 10.3% of incident light. Reflectance is perceived by both the wearer and the observer. Eyeglass wearers may notice ghost images such as their own eye or eyelashes, which may cause a distraction if not accustomed. Observers may see ghost images or glare within the lenses of the wearer. When applied to transparent surfaces such as spectacle lenses, AR coatings are able to reduce the surface reflections to less than 1% of the incident light. Ghost images are reduced, glare is reduced, and objects appear to be more brightly lit thru AR lenses[4-6].

This study proposed to better quantify the perceived effect of antireflective coatings on various daily activities, concentrating on tasks such as driving, computer use, and usage of handheld devices. It also measured contrast sensitivity thru AR and non-AR lenses to determine how significant of an effect was measurable at different acuity levels. Additionally, contrast sensitivity was measured under glare conditions while subjects wore both AR and non-AR lenses.

## Methods

Participants were enrolled categorically in this study in order to mimic the United States demographic in regard to age, race, gender, and refractive error. Adult subjects could range upwards in age from 18 years but all were required to achieve no less than 20/20 acuity at distance and near as tested with Snellen letters. All were also required to be binocular and free of any ocular disease that would potentially inhibit either visual acuity or contrast sensitivity, i.e. healthy subjects. Participants were all current full-time or close to full-time spectacle wearers and all spent at least a portion of their time at a computer. US Census data[7] was utilized to determine the percentage of the US population falling into the categories of Caucasian male aged 18-34, 35-49, 50+, Caucasian female aged 18-34, 35-49, 50+, African American male aged 18-34, 35-49, 50+, and African American female aged 18-34, 35-49, 50+. These numbers were then used to enroll the aggregate number of individuals in each category, as closely as possible, into the study. Participants were further selected in order to reflect the latest-reported prevalence of refractive error in the US[7-10] and categorized as myope, hyperope, or astigmat. Presbyopia was not a separate category as this was considered a reflectance of age group. The end demographic product is shown in Tables 1 and 2. 46 subjects completed the study.

**Table 1. Demographic breakdown of study participants vs US population.**

| | Percentage of US population | |
|---|---|---|
| Male 18-34 Caucasian | 13.3 | 12.2 |
| Male 18-34 African American | 2.2 | 2.4 |
| Male 35-49 Caucasian | 11.8 | 9.8 |
| Male 35-49 African American | 2.0 | 2.4 |
| Male 50+ Caucasian | 16.6 | 12.2 |
| Male 50+ African American | 2.8 | 0 |
| Female 18-34 Caucasian | 12.8 | 17.1 |
| Female 18-34 African American | 2.3 | 2.4 |
| Female 35-49 Caucasian | 11.7 | 12.2 |
| Female 35-49 African American | 2.1 | 4.9 |
| Female 50+ Caucasian | 18.8 | 22.0 |
| Female 50+ African American | 3.4 | 4.9 |

**Table 2. Refractive error breakdown of study participants vs US population.**

| | Percentage of US population | Percentage of study population |
|---|---|---|
| Myopes | 33.1 | 36.6 |
| Hyperopes | 22.1 | 24.3 |
| Astigmats | 36.2 | 39.0 |

Subjects were examined and fitted for spectacles of the same type habitually worn (i.e. single vision, bifocal, progressive lenses). Frame selection was appropriate for type of lens fitted. An off-site laboratory manufactured at least 2 complete pairs of glasses for each study subject, each in identical frames. One pair contained polycarbonate lenses with scratch coating, the other pair contained polycarbonate lenses with scratch coating and a premium antireflective coating. Parameters were verified upon receipt, as were OD, OS, OU acuities of at least 20/20.

This was a crossover designed study, double-masked, in which subjects were randomized as to which pair of spectacle lenses (AR vs. non-AR) were initially dispensed. Subjects filled out an intake questionnaire, were provided with pair #1, and given a lens cloth with identical directions for care and cleaning to be used with all spectacles. Subjects were asked to wear the glasses as they normally would for approximately 2 weeks' duration. At follow up they were asked to again fill out a questionnaire and were tested for visual acuity and contrast sensitivity levels. Glasses were switched at that visit to pair #2 with similar instructions. The process was repeated at follow up and glasses were again switched back to pair #1, although the subjects believed them to be a separate pair #3. Final follow up included the corresponding questionnaire and testing, and the subject was able to choose to keep his/her preferred pair of glasses.

The majority of enrolled subjects used their glasses on a full time basis and were tested for acuity and contrast sensitivity using the M&S Technologies Inc. Smart System II 20/20™ Visual Acuity & Fixation System[11]. Testing was performed in the same location and with the same equipment for each subject. Two participants used their glasses primarily for intermediate and near activities and were tested for contrast sensitivity using the Freiburg Visual Acuity & Contrast Test[12].

The M&S Smart System 20/20™ Letter Contrast Test uses Sloan letters as the target. Contrast is determined using pixel density to set the gray value to the percent of contrast between the black and white monitor values. Monitor benchmark settings were predetermined and for this study utilized brightness level at 1%, contrast level at 50%, and color settings at R=93, G=67, B=0. Room lights remained on for acuity testing but were turned off for contrast testing. The procedure for determining threshold of contrast sensitivity incorporated three levels of acuity: 20/30, 20/50, and 20/70. For each acuity level a suprathreshold contrast target was provided (typically 63%) and contrast was reduced until the subject was unable to see at least half of the target letters. This level was noted and then contrast was reduced further to infrathreshold levels at least 3 lines below the noted value. Contrast was then increased until the subject was again able to see at least half of the target letters. The higher of the two percentages (decreasing or increasing) was used as the final recorded value. Glare testing utilized this same threshold measurement with the addition of a Brightness Acuity Tester (BAT, Marco) set to medium. Glare testing was done monocularly on all subjects at distance using a 20/70 target.

The Freiburg Visual Acuity & Contrast Test is a computerized forced-choice test which uses a Landolt-C contrast sensitivity target. Subjects were positioned at approximately a 5 foot test distance in a darkened room. Pixel quality on the computer monitor precluded testing at any closer range. Near Snellen acuity was confirmed on these patients, as that was the method utilized upon enrollment.

## Results

Contrast sensitivity data as well as questionnaire results were compiled and analyzed for both objective and subjective responses.

Contrast sensitivity testing was analyzed OU at the 20/30, 20/50, and 20/70 acuity levels in subjects (n=44) completing the M&S test. Analysis of variance (using a repeated measures design) (ANOVA) results indicate that there was not a statistically significant effect of coating (F=2.57, p=0.116) as shown in Table 3. There was a significant effect of letter size, expected in such testing.

**Table 3. Statistical comparison of contrast sensitivity values in AR vs non-AR lenses.**

| Contrast Sensitivity Level | AR* | No AR* | p Value** |
|---|---|---|---|
| 20/30 | 12.52 ± 5.58 | 13.15 ± 5.51 | 0.424 |
| 20/50 | 6.94 ± 3.06 | 7.50 ± 3.34 | 0.157 |
| 20/70 | 5.14 ± 1.83 | 5.54 ± 2.10 | 0.257 |

* Data presented as mean %CS ± standard deviation
** when comparing AR vs No AR

Responses (n=46) were analyzed to determine patient perception of visual clarity and visual comfort overall, and during particular tasks such as driving, using desktop/laptop computers and using handheld devices. Subjects were also queried throughout the study as to whether they would be likely to repeat this lens choice and/or recommend each pair of lenses. These assessments were compared via nonparametric t-test and AR lenses were found to produce significantly more positive responses than non-AR lenses, as shown in Figures 1 and 2. In addition, when measuring contrast sensitivity under conditions of moderate glare, AR lenses were notably superior (Z= -2.124, p=0.034) as shown in Figure 3.

**Figure 1. Subject preference using AR and non-AR lenses.**

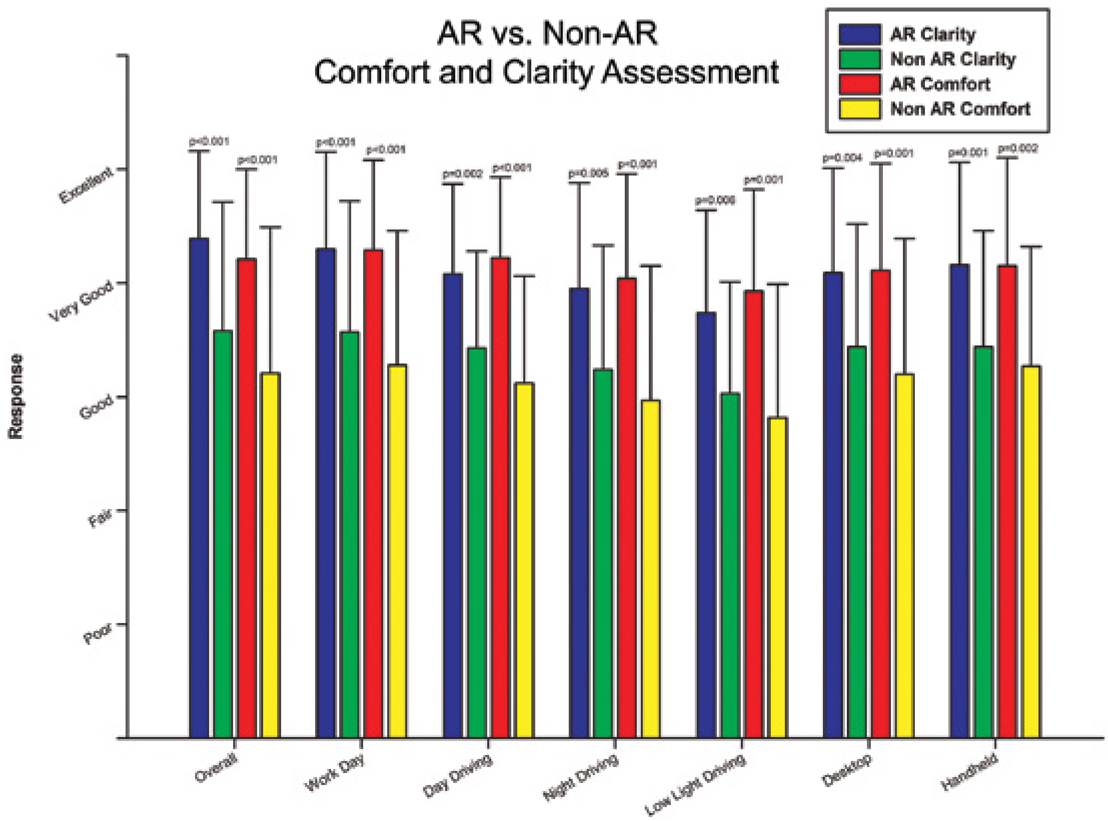



**Figure 2. Likelihood of subjects to recommend/repeat lens choice.**

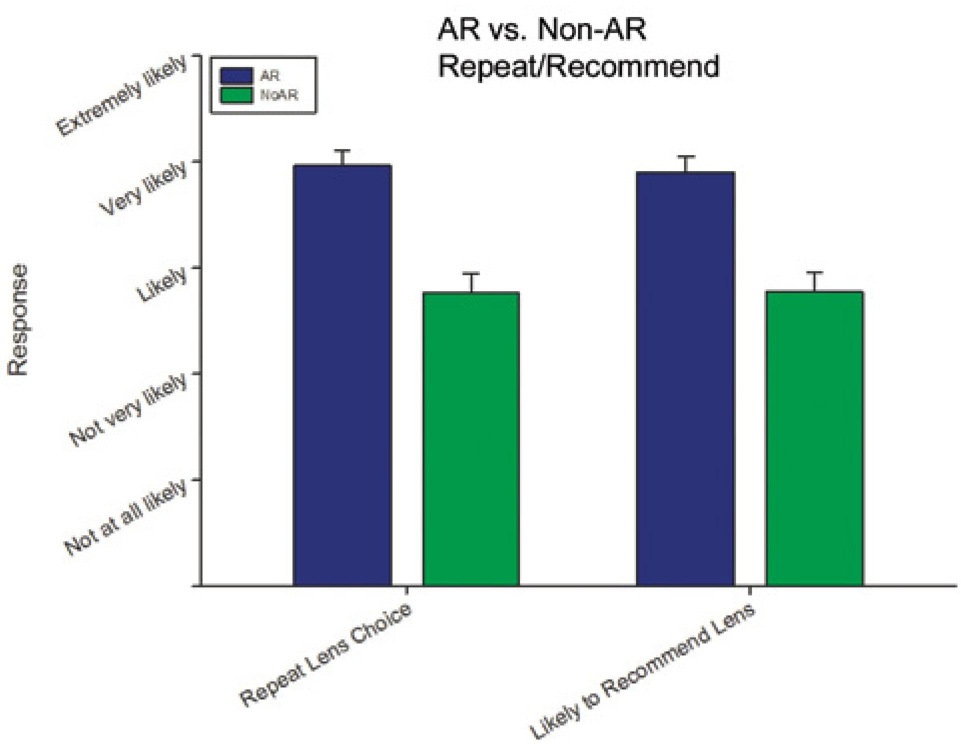
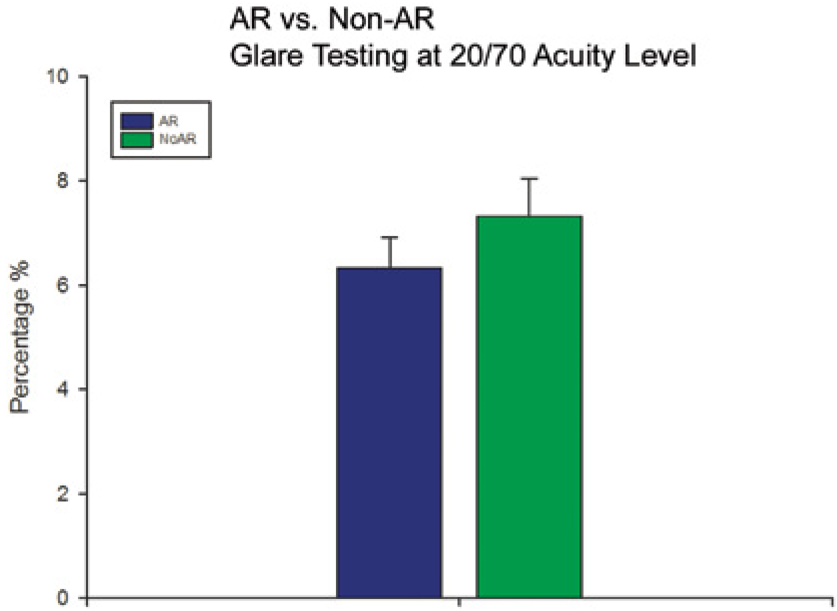


**Figure 3. Glare threshold measured during contrast sensitivity testing.**




Subjects, on average, read one additional line of text under moderate glare conditions when using AR lenses.

36 of the 46 subjects (78.3%) chose to keep the AR lenses as their preferred pair. 10 subjects (21.7%) kept the non-AR lenses. Throughout the study, participants were given the opportunity to offer comments and feedback after wearing each pair of lenses. A sample of those subjective responses is presented in Table 4, but it is not in the scope of this paper to offer additional analysis of these responses.

**Table 4. Sampling of comments from study participants wearing lenses with and without AR.**

| AR lenses | Non-AR lenses |
|---|---|
| My vision seemed clearer with these glasses and my eyes feel less tired when I'm studying on the computer. | I disliked the aberrations in the corners of the lens. If I would move my eyes to look out of my side vision, it would be distorted and I would have to move my head. (Subject is not a PAL wearer.) |
| I am far less aware of the glasses as I don't see halos or reflections much if at all. I don't seem to be removing them as often. | I can't say there was anything specific, but this pair just didn't seem as sharp. |
| Comfortable and clear. I forgot I was wearing them. | Vision was not as sharp. Driving at night was very poor. Lots of glare. |
| My vision was clearer and sharper, and colors were more vibrant thru these lenses. | Lots of glare. While driving, numerous times thought there was something in my view when it was just glare. Couldn't work at my computer long without strain. |

## Discussion

Previously published studies comparing the relationship between AR and non-AR spectacle lenses have utilized CR-39 as the lens material[4-6]. Results were reported for relatively small study populations (4, 23, and 19 participants, respectively). Visual performance was subjectively reported in each study, and in the first two studies contrast sensitivity was utilized as a means of comparing CR-39 AR and non-AR lenses. While CR-39 is still a common lens material, for a variety of reasons many consumers are now wearing higher index lenses. And while not attempting to recreate the earlier studies insofar as design or environment, this study sought to confirm that their conclusions regarding the benefits of AR apply to higher index lenses as well. The reflectance of CR-39 at 7.59%, when compared to the reflectance of hi-index plastic at 10.39%, often translates into wearers of hi-index materials being more conscious of aberrations or reflected images. Since AR reduced such complaints in traditional plastic lenses, it was expected that the same would apply to hi-index. And indeed, this premise was correct. Participants subjectively reported less glare, noted minimal reflections, and exhibited improved contrast thru AR polycarbonate lenses. Statistically, the analysis of contrast sensitivity being affected by AR alone fell short of clinical significance. Increasing the sample size may alter this value, but the conclusion itself is still supported by the analysis of variance. Larger target size predictably improved contrast sensitivity. Glare conditions were created by using the BAT at its medium setting in a darkened room. Target size of 20/70 was equivocal but also chosen due to its value at or near the driving limit in some states[13]. Threshold values improved with AR lenses, allowing subjects to read on average one line of additional low contrast letters. Subjects had no disposition toward glare difficulty (no presence of cataract etc) yet still performed better using AR lenses. Future study may be beneficial if incorporating subjects known to have increased glare difficulty. Additional conclusions drawn from previous studies regarding performance of CR-39 AR lenses are also supported within this study using polycarbonate AR lenses; wearers subjectively preferred AR lenses.

## Conclusion

Based on data collected from a wide demographic of patients spanning known refractive errors, the majority of subjects displayed a clear preference for AR lenses over non-AR lenses. Subjectively the AR lenses provided better clarity and comfort when performing normal daily activities and tasks including driving, working at a computer and using a handheld device. Objectively contrast sensitivity was improved thru the AR lenses when compared to non-AR lenses, although the statistical level was not significant. Subjects were also more likely to recommend AR lenses and would continue to wear them in the future. Further evaluation of data as well as larger sample size inclusive of subjects at various levels of acuity would produce additional insight into determining objective and subjective benefits of antireflective lenses. Recommending AR on all lenses, regardless of material, benefits the wearer by reducing glare, improving contrast, and enhancing both acuity and comfort.

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## Conflict of interest statement

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