# Validation of the Effect of Glare on Contrast Sensitivity Under Mesopic and Photopic Conditions

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## INTRODUCTION/ABSTRACT

Contrast sensitivity (CS) has been a staple of optometric testing for 40+ years. Glare testing has been mostly research based. CS testing is used to measure the performance of optical corrections from contact lenses, to ophthalmic lenses to IOL implant lenses, particularly multifocal IOL's. Clinical CS testing is often quite time consuming and glare testing has not established itself yet in the clinic. This new Bull's eye concentric rings, sine-wave grating target and the automated testing protocols combine CS and glare testing in an easy to use testing system for both research and clinical use. This study was undertaken to validate the testing system and methods for both research and clinical use and to determine the precise level of glare that would decrease CS by 0.1 log across as many spatial frequencies as possible.

## METHODS

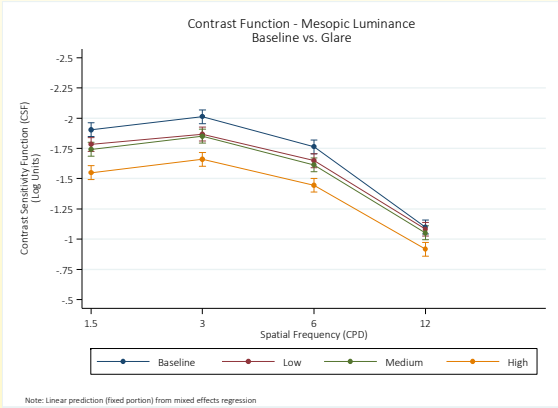
105 subjects were recruited from the SCO student population with the following characteristics: 23 male 82 female, average age 25 years 3 months ranging from 22 years 8 months to 40 years 4 months, best corrected visual acuity was 20/20 or better in each eye. Visual acuities were tested using the Automated ETDRS testing protocol which is part of the Clinical Test Suite (CTS) M&S Technologies Systems. All testing was done with all the lights in the room off and background luminance was verified to be 0 cd/m2. Prior to each testing session the system is calibrated with both background screen luminance and average luminance of the target set to 85 cd/m2.

The CTS system appears to the left, with the Bull's Eye target as seen by the subjects with the glare lights off. Four glares lights were chosen surrounding the screen to give an equal distribution of light over the surface of the eyes. Each light is covered by a diffuser to mitigate optical aberrations. Subjects sat 8 feet from the screen and had placed before them a tablet which was paired to the computer via Bluetooth. Testing at each spatial frequency involved begins supra-threshold and steps down, following a proprietary staircase algorithm, and presents either the target or nothing. Subjects responded on the tablet by touching the bull's eye on the left or the blank target on the right. (pic beginning of next column)


CS was measured under mesopic (4 spatial frequencies) and photopic conditions (5 spatial frequencies) with three different levels of glare and with no glare at all, for a total of 36 different testing conditions. An automatic stepping paradigm was used which made the testing quick and efficient; all 36 thresholds were identified in about 25 minutes of testing. A digital lux meter was positioned directly where the subject's face would be and the glare lights were calibrated prior to beginning the study to: LOW = 120 lux, MEDIUM = 180 lux and HIGH = 450 lux. To conduct the mesopic tests, subjects were dark adapted from 5 minutes prior to beginning testing and a large filter was placed over the entire CTS including the 4 glare lights reducing all light levels bot 3.53% of the photopic levels.

## RESULTS

The CS plots for all conditions under mesopic and photopic thresholds were plotted and compared statistically. The results showed that all levels of glare reduced CS. The low and medium levels of glare reduced CS to about the same level; both were significantly different than no glare but were not different from each other. High glare reduced CS statistically significantly from both the no glare and from both the low and medium glare conditions.




The graph to the left shows the results for testing under mesopic conditions at each of the four spatial frequencies tested. The highest line is the no-glare baseline condition showing maximum CS without glare. The bars above and below each data point show the 95% confidence interval (CI). The lowest line is the HIGH glare and the two, almost superimposed lines in the middle represent the LOW and MEDIUM glare conditions.

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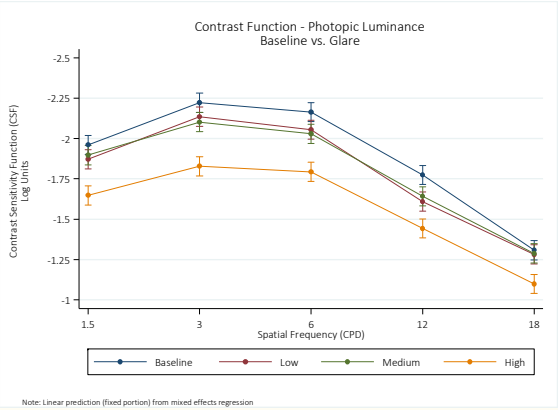
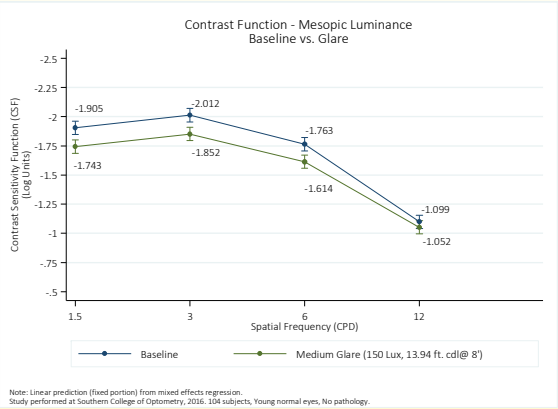
## RESULTS (continued)

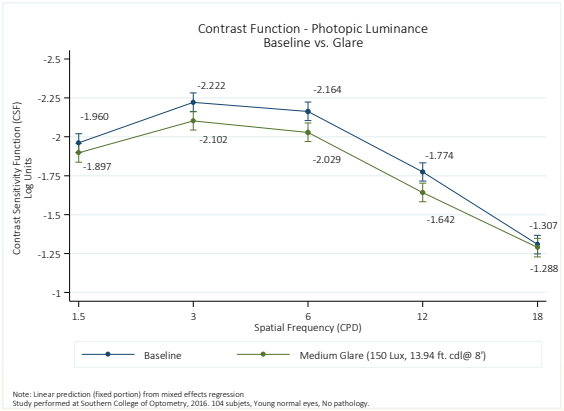



The graph to the left shows the results for testing under photopic conditions at each of the five spatial frequencies tested. The configuration of the lines, with the no-glare baseline condition on top and the HIGH glare on the bottom with the other conditions in the middle repeats itself here.




The graph on the left shows the results for testing under mesopic conditions for just the baseline and the MEDIUM level of glare at each of the four spatial frequencies tested. The numbers above and below each point show the actual values for CS in log units.

## RESULTS (continued)




The graph left shows results for photopic conditions for baseline and MEDIUM glare at each of the five spatial frequencies tested. The numbers above and below each point show the actual values for CS in log units.

The table below shows the values from which the graphs were made for the mesopic functions. The statistical model was linear mixed effects regression predicting the contrast sensitivity value, with fixed factors for Level of glare, Frequency (cpd), Level x Frequency interaction, and a subject-specific intercept. Values from simple mean estimation of the raw data calculated at each Level of Glare and Frequency are also shown.

| | | Statistical Model (mixed effects regression) | | | Raw Data (mean estimation) | | |
|---|---|---|---|---|---|---|---|
| | Mean | Δ-method SE | 95% Confidence Interval lower | upper | SE of Mean | 95% Confidence Interval lower | upper |
| **Baseline** | | | | | | | |
| 1.5 cpd | -1.905 | 0.029 | -1.962 | -1.848 | 0.026 | -1.956 | -1.853 |
| 3 cpd | -2.012 | 0.029 | -2.069 | -1.955 | 0.022 | -2.056 | -1.969 |
| 6 cpd | -1.763 | 0.029 | -1.820 | -1.706 | 0.022 | -1.805 | -1.721 |
| 12 cpd | -1.099 | 0.029 | -1.156 | -1.042 | 0.021 | -1.140 | -1.058 |
| **Low Glare** | | | | | | | |
| 1.5 cpd | -1.783 | 0.029 | -1.841 | -1.726 | 0.027 | -1.837 | -1.730 |
| 3 cpd | -1.868 | 0.029 | -1.925 | -1.811 | 0.048 | -1.962 | -1.774 |
| 6 cpd | -1.649 | 0.029 | -1.706 | -1.592 | 0.027 | -1.702 | -1.595 |
| 12 cpd | -1.082 | 0.029 | -1.139 | -1.025 | 0.026 | -1.133 | -1.031 |
| **Medium Glare** | | | | | | | |
| 1.5 cpd | -1.743 | 0.029 | -1.800 | -1.686 | 0.030 | -1.801 | -1.685 |
| 3 cpd | -1.852 | 0.029 | -1.909 | -1.795 | 0.042 | -1.935 | -1.769 |
| 6 cpd | -1.614 | 0.029 | -1.671 | -1.557 | 0.027 | -1.667 | -1.561 |
| 12 cpd | -1.052 | 0.029 | -1.109 | -0.995 | 0.023 | -1.097 | -1.006 |
| **High Glare** | | | | | | | |
| 1.5 cpd | -1.550 | 0.029 | -1.607 | -1.493 | 0.026 | -1.600 | -1.499 |
| 3 cpd | -1.660 | 0.029 | -1.717 | -1.603 | 0.028 | -1.714 | -1.606 |
| 6 cpd | -1.445 | 0.029 | -1.502 | -1.388 | 0.027 | -1.499 | -1.392 |
| 12 cpd | -0.916 | 0.029 | -0.973 | -0.859 | 0.033 | -0.980 | -0.852 |

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## RESULTS (continued)

The table below shows the specific values for the pooled photopic data. Data were examined using mixed effects linear regression, fitting separate models for experiments at Photopic and Mesopic luminance. The dependent variable for each model was the log contrast sensitivity value. Fixed parameters included a Spatial Frequency factor (in cycles per degree, for Photopic: 1.5, 3, 6, 12, and 18; for Mesopic: 1.5, 3, 6, and 12), a Glare level factor (baseline, low, medium, and high), and their interaction to characterize the effect of Glare level at each Spatial Frequency. Each model included a subject-specific random intercept to account for repeated measurement on the same individuals. Model-predicted means, standard errors, and 95% confidence intervals were computed. Statistical significance was tested for contrasts at each spatial frequency comparing baseline against each level of Glare (i.e., baseline vs. low; baseline vs. medium; baseline vs. high). Finally, contrasts comparing low to medium glare were examined at each Spatial Frequency. The first is a mixed effects regression analysis and the second is simple mean estimation of the raw data calculated separately at each Level of Glare and Frequency.

| | | Statistical Model (mixed effects regression) | | | Raw Data (mean estimation) | | |
|---|---|---|---|---|---|---|---|
| | Mean | Δ-method SE | 95% Confidence Interval | | SE of Mean | 95% Confidence Interval | |
| | | | lower | upper | | lower | upper |
| **Baseline** | | | | | | | |
| **1.5 cpd** | -1.960 | 0.030 | -2.019 | -1.901 | 0.060 | -2.079 | -1.842 |
| **3 cpd** | -2.222 | 0.030 | -2.282 | -2.163 | 0.018 | -2.257 | -2.187 |
| **6 cpd** | -2.164 | 0.030 | -2.223 | -2.105 | 0.021 | -2.205 | -2.123 |
| **12 cpd** | -1.774 | 0.030 | -1.833 | -1.715 | 0.026 | -1.826 | -1.722 |
| **18 cpd** | -1.307 | 0.030 | -1.367 | -1.248 | 0.026 | -1.358 | -1.257 |
| **Low Glare** | | | | | | | |
| **1.5 cpd** | -1.872 | 0.030 | -1.931 | -1.812 | 0.043 | -1.955 | -1.788 |
| **3 cpd** | -2.136 | 0.030 | -2.195 | -2.077 | 0.018 | -2.171 | -2.101 |
| **6 cpd** | -2.055 | 0.030 | -2.114 | -1.996 | 0.025 | -2.105 | -2.005 |
| **12 cpd** | -1.609 | 0.030 | -1.668 | -1.550 | 0.059 | -1.724 | -1.494 |
| **18 cpd** | -1.282 | 0.030 | -1.341 | -1.222 | 0.025 | -1.331 | -1.233 |
| **Medium Glare** | | | | | | | |
| **1.5 cpd** | -1.897 | 0.030 | -1.956 | -1.838 | 0.018 | -1.933 | -1.861 |
| **3 cpd** | -2.102 | 0.030 | -2.161 | -2.043 | 0.020 | -2.141 | -2.063 |
| **6 cpd** | -2.029 | 0.030 | -2.088 | -1.970 | 0.021 | -2.070 | -1.988 |
| **12 cpd** | -1.642 | 0.030 | -1.701 | -1.583 | 0.027 | -1.695 | -1.588 |
| **18 cpd** | -1.288 | 0.030 | -1.347 | -1.229 | 0.027 | -1.340 | -1.236 |
| **High Glare** | | | | | | | |
| **1.5 cpd** | -1.647 | 0.030 | -1.707 | -1.588 | 0.023 | -1.692 | -1.603 |
| **3 cpd** | -1.828 | 0.030 | -1.887 | -1.769 | 0.024 | -1.876 | -1.780 |
| **6 cpd** | -1.794 | 0.030 | -1.853 | -1.734 | 0.027 | -1.846 | -1.741 |
| **12 cpd** | -1.443 | 0.030 | -1.502 | -1.383 | 0.026 | -1.494 | -1.391 |
| **18 cpd** | -1.098 | 0.030 | -1.158 | -1.039 | 0.027 | -1.152 | -1.045 |

## DISCUSSION

For Photopic Luminance, all glare levels differed significantly from baseline at each spatial frequency at the p<.05 level or higher, with the following three exceptions where there was no significant difference from baseline: (1) low glare at 18 cpd (p= .47), (2) medium glare at 18 cpd (p= .58), and low glare at 1.5 cpd (p=.07). For Mesopic Luminance, only two glare levels did not differ significantly from baseline (all ps < .05, except): (1) low glare at 12 cpd (p= .57), and (2) medium glare at 12 cpd (p= .12).

*Low vs. Medium Glare*

Because the low and medium glare levels yielded very similar contrast sensitivity functions, these were compared directly to determine if there was a statistically discernible difference. There were no significant differences between low and medium glare levels, at any Spatial Frequency, for either Photopic or Mesopic Luminance experiments (Photopic: ps= .48, .34, .46, .35, and .89 for 1.5, 3, 6, 12, and 18 cpd, respectively; Mesopic: ps= .19, .60, .26, and .33 for 1.5, 3, 6, and 12 cpd, respectively). Hence, the findings suggest that low and medium glare levels as used in the current study are redundant.

*Light Levels*

In a pilot version of this study all of the glare light levels were much lower with the prior value for HIGH set at the current MEDIUM value scaled down from there. In some subjects, the LOW level of glare actually showed a slight improvement in CS, which we believe may have been from a small amount of pupillary constriction which not only countered the glare factors but may have actually helped to enhance CS. At the levels chosen here we had hoped to get a better stratification of the data but still found that LOW and MEDIUM were functionally interchangeable.

## CONCLUSIONS

The results validate the use of this new sine wave Bull's eye target for measuring CS as well as identifying the levels of glare which drop CS by specific amounts. These curves will provide the basis for determining how well different contact lenses, ophthalmic lenses and IOL's perform under glare conditions and should lead to the development of clinical testing protocols for diagnosing conditions such as cataract, macular degeneration and epi-retinal membranes to name a few.

## REFERENCES


1. "Contrast Sensitivity and Glare Testing in the Evaluation of Anterior Segment Disease", American Academy of Ophthalmology Committee on Ophthalmic Procedures Assessment, published in *Ophthalmology*, Volume 97, Issue 9, September 1990, pages 1233-1237
2. Koch, D.D., Glare and contrast sensitivity testing in cataract patients, J Cataract Refract Surg, 1989 March 15(2):158-164
3. Williamson, TH, Strong, NP, et al., Contrast sensitivity and glare in cataract using the Pelli-Robson chart, British Journal of Ophthalmology 1992;76: 719-722
4. Miller, David, "Glare and Contrast Sensitivity", book chapter online: http://80.36.73.149/almacen/medicina/oftalmologia/enciclopedias/duane/pages/v1/v1c035.html
5. FDA Executive Summary prepared for the November 14, 2014 meeting of the Ophthalmic Devices Panel of the Medical Devices Advisory Committee, Premarket Approval Application P040020/S049
6. Martin, L., Computerized method to measure glare and contrast sensitivity in cataract patients, J Cataract Refract Surg. 1999 March; 25(3): 411-415.


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