What is the Utility of the Psychophysical ‘Light Scattering Factor’?

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It has been suggested by Sjöstrand and his colleagues that an index of scatter by the ocular media may be derived from contrast sensitivity measured with and without a glare source. This index was tested under different conditions of stimulus luminance and found not to be constant and thus to not reflect a property of the media. Invest Ophthalmol Vis Sci 33:688-690, 1992

Vos, Walraven, and van Meeteren have proposed an empirical light scattering factor for the ocular media (LSF) in terms of the illuminance on the eye from a glare source (E), an equivalent veiling luminance (L_{eq}), and the glare angle (GA). Rearranging their equation (3) gives the following expression:

\[ LSF = \frac{L_{eq}}{E} \]

Paulsson and Sjostrand report the LSF for five subjects without cataracts, with contrast thresholds measured by the ascending method of limits at five spatial frequencies from 2.0–7.0 cycles per degree, and with a range of two log units of L (E remaining constant). The value of LSF was different, by a factor of 1.71–0.47 for different subjects, with a one-log-unit change in L. Thus, this number does not seem to express simply a characteristic of the scattering media.

Abrahamsson and Sjöstrand pointed out that the earlier LSF calculation should include a correction factor (CF) to account for changes in the pupil due to the glare source. They proposed a modified expression:

\[ LSF = \frac{L}{E} \times \left[ \left( \frac{CF}{L/M} - 1 \right) \times \frac{L_{eq}}{E} \right] \]

Abrahamsson and Sjöstrand used a value of 1.2 for CF, and they stated that “the factor 1.2 was empirically determined,” with no further explanation.

In this paper, we report an experiment intended to test equation (3) further. In particular, if a value for CF that held for all subjects could be found, the expression could be useful for comparing the results from different laboratories and clinics, and different stimulus and procedural conditions. Direct measurements of pupil diameters with and without the glare source were made, to correlate with the CFs for individual subjects.

Methods. Twelve observers were used. Eye color ranged from dark brown to light blue. Subjects ranged in age from 22–50 years. Inclusion criteria were the absence of any visible or known ocular pathology, clinically clear media, and a corrected visual acuity of at least 20/30. Subjects and results are listed in Table 1. Informed consent was obtained from all subjects after the nature of the procedures in the experiment had been explained fully.

Contrast threshold stimuli were vertical antisymmetric one-dimensional Gabor patterns produced on a Tektronix 608 oscilloscope (Tektronix, Inc., Beaverton, OR) with no surround field. The stimuli had a fundamental spatial frequency of two cycles per de-
grees, a duration and inter-stimulus interval of 500 ms, and abrupt temporal onsets and offsets. The viewing distance was 3 m. At this distance, the screen subtended 2.4° horizontally and 1.8° vertically. All subjects were carefully refracted for the viewing distance, and the best correction was used with a trial frame. All subjects required some correction for this distance, so there were no differences between subjects regarding the number of extraocular scattering surfaces involved. Viewing was monocular with the natural pupil. The mean screen luminance was either 10.08 candlepower/m² or 2.03 cd/m². A current-regulated tungsten glare source with a 2 mm diameter filament was placed 1.5 m from the observer and 3.5° visual angle to the right of the center of the stimulus screen. Glare illuminance at the cornea was 18.8 lumens/m². All calibrations were done with a Pritchard photometer (Photo Research, Chatsworth, CA).

Each subject’s head was inside an opaque enclosure that was painted flat black. The glare source was projected onto the eye through a hole in the enclosure, and the stimulus was viewed through the same opening. The experimental room also was painted flat black, and the stimulus screen was baffled from any residual ambient illumination. No increase in luminance of the screen could be detected with the photometer when the glare source was turned on.

We used a temporal two-alternative forced-choice procedure, combined with a double random-alternating staircase, to generate psychometric functions. The two staircases converged on the stimulus values that would give 0.71 and 0.84 proportion correct responses. Four sessions were run with each subject. In each session, measurements were made in the order of “no-glare:glare:glare:no-glare.” Trials were pooled at each stimulus level, and the 75% correct point (contrast threshold) was estimated with probit analysis.

There were approximately 300 trials in each psychometric function.

With the subject viewing the stimulus screen, at high or low luminance, the pupil was photographed with a macro-telephoto camera lens, with and without the glare source. For calibration, a millimeter ruler was held at the same plane as the pupil and photographed simultaneously. Pupil diameters were measured from projected images of photographic slides. The ratio (pupil diameter, glare):(pupil diameter, no glare) was calculated for each subject. (The screen luminance had no effect on these measurements because the illuminance from the screen was insignificant in relation to the illuminance from the glare source.)

**Results.** Subject characteristics and results are given in Table 1.

We calculated the LSF for measurements at two different levels of screen luminance, with glare illuminance held constant, from equation (2). The average LSF was 0.57 with the high luminance stimulus and 0.26 for the low luminance stimulus, significantly different at $P < 0.03$ with a t-test and the Mann-Whitney U Test, confirming that equation (2) is not an appropriate method of determining an intrinsic scattering factor.

We then assumed that the CF in equation (3) was chosen so the LSF would be independent of the values of $L$ and $E$, the intensity of the original formulation (equation [2]). For each of the subjects, we derived the CF for equation (3) that would produce equal LSFs for the high and low luminance stimuli. The values of CF for the different subjects ranged from 0.32—4.82, with a mean of 1.58 and a standard deviation of 1.52. Clearly, a single CF cannot be used for all subjects, as Abrahamsson and Sjöstrand suggested. Thus, the utility of the formulation in equation (3) also is questionable.

**Discussion.** What produces the different CFs for different subjects, and can the LSF concept be made useful through more kinds of information?

In the range used in this experiment, stimulus luminance itself had no effect on contrast thresholds. Mean log contrast thresholds with no glare were $-1.43$ for low luminance and $-1.47$ for high luminance stimuli.

Within each of the four conditions, there was no correlation between contrast threshold and pupil diameter (and thus retinal illuminance).

There was a slight tendency for the CF to be smaller with larger pupil ratios, ie, the CF was smaller in those subjects whose pupils were affected less by the glare source. The $r$ value for the correlation was only 0.49.

There was a tendency for the correction factor to

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**Table 1. Subject characteristics and data**

<table>
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<tr>
<th>S</th>
<th>AGE</th>
<th>LSF-L</th>
<th>LSF-H</th>
<th>CFAC</th>
<th>Pupil/R</th>
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</table>

LSF-L: light-scattering factor, low luminance; LSF-H: light-scattering factor, high luminance; CFAC: correction factor, equation (3); Pupil/R: (pupil diameter with glare)/(pupil diameter no glare).
decrease slightly with age; the correlation was not strong ($r = 0.61$).

The psychophysical estimate of a "light scattering factor," from contrast thresholds and the use of equations (2) or (3), is not a reliable procedure. No single correction factor for equation (3) was found that would produce the same result for all subjects at different screen luminances. Furthermore, the correction factor was not related strongly to a number of other measurable characteristics of the subjects, so it cannot be determined independently for each subject other than from the data on glare effects.

In conclusion, in studies of the effects of glare on visual performance (as with all scientific reports), stimulus conditions, procedures, and characteristics of subjects should be reported in great detail. Data should not be presented in the form of derived measures until those measures have been thoroughly validated.

Key words: lens; glare; scatter; pupil; psychophysics

References