

# Glare

## Part 2 - Ocular straylight and disability glare

In the second of our short series looking at glare, **Dr Ian Murray** describes some methods of evaluating ocular light scatter and disability glare. **C7654**, one general CET point for optometrists and dispensing opticians

**A**ccording to the CIE, 'disability glare' is defined as 'visual conditions in which there is excessive contrast or an inappropriate distribution of light sources that disturbs the observer or limits the ability to distinguish details and objects.'<sup>1</sup>

Non-uniform lighting, inducing excessive blinking, ocular spasms and even pain is referred to as 'discomfort glare'. Conventionally, the two types of glare have been regarded as different results of the same phenomenon; the eye cannot simultaneously process extreme differences in intensity levels.

There is thus no unique link between the two forms of glare and there will often be overlap between them. This article is mainly concerned with disability glare.

### Underlying principles and mechanisms

Disability glare gives the impression of a veil of light being thrown over a person's vision. It occurs when light from an intense light source situated in an otherwise normally illuminated or dim environment is incident on the eye.

A commonly experienced example of disability glare is caused by oncoming headlights. Here, the extent of disability, although momentary, can be particularly distressing and may give rise to a total loss of vision. The cause is two-fold. First, there is a neural component related to the period of light adaptation required by the photoreceptors. This is illustrated in Figure 1 where the physical luminance of the annulus is constant, but appears to change depending on whether it has a light or a dark background. The effect is referred to as induction. Second, is the reduction of contrast in the retinal image due to intraocular light scatter.

The extent of disability is classically expressed in terms of equivalent veiling

luminance,  $L_v$ , illustrated in Figure 2. This is the luminance of a uniform light required to reduce the visibility of a target by the same amount, as does the glare source.

Following the pioneering work of Stiles and Holladay,<sup>2</sup> veiling luminance  $L_v$  (cd/m), due to a point source is expressed as:

$$L_v(\theta) = \frac{10E}{\theta^2} \quad \text{for } 1^\circ < \theta < 30^\circ \quad (1)$$

Where  $E$  = incident illumination (Lux)  
 $\theta$  = the angle between the line of sight and the glare source (degrees)

The equation simply confirms everyday observation; visibility of a target is reduced as the glare source is increased in intensity and as its angle of incidence approaches that of the line of sight. Note, however, that the relationship does not hold for small angles. It is apparent that neural effects exaggerate the contrast loss for small angles of incidence.<sup>3</sup>

Light incident on the retina causes forward scatter and this is differentiated from back-scatter, which occurs when light is reflected from the various ocular components. The latter, of course, can be viewed with a slit-lamp but may be unrelated to the forward scatter and therefore to the disability glare experienced by a patient.

Light is scattered by small particles in the transmitting media. As seen in Figure 3, the scattering properties of a medium depend on the size of the particles of which it is composed.

Rayleigh scattering applies to small spherical particles ( $\sim \lambda/10$ ) and therefore short-wave light is scattered more than long-wave light. Rayleigh scatter accounts for the blue appearance of a clear sky because it is caused by air molecules and forward and backward scatter are equivalent.

So-called Mie scatter is a more general description of light scatter, not necessarily limited by the size of the particles in the

medium. It accounts for the achromatic colour of clouds, which are composed of water droplets. Usually scatter in the human eye is not wavelength-dependent and can be assumed to be of the Mie form. Hence, forward and backward light scattering properties of the ocular media are different. This is an important observation. It means that directing light into the eye and observing the scattering characteristics does not help to evaluate the degradation of the retinal image and therefore the disability glare caused by the light.

### Relevance to ophthalmic practice

Ocular scatter and disability glare in the normal eye - the 'Straylight hypothesis'

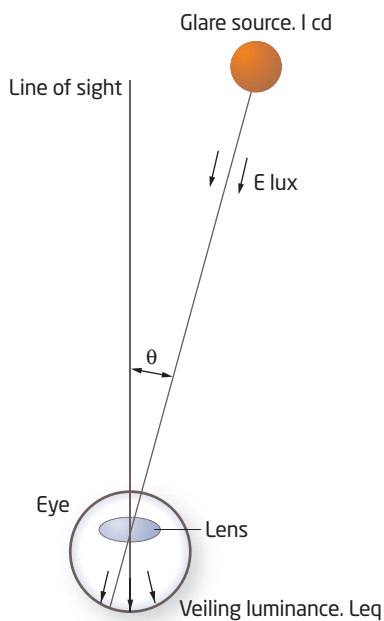
Although it is accepted that there is neural element to disability glare, the idea that the effect is due mainly to the normal light scattering properties of the eye is now universally accepted. The theory of veiling luminance predicts that the effect is linearly related to the intensity and size of the glare source. This has been tested in many experiments, over many decades and, as described in Equation 1, veiling luminance has been shown to be strictly proportional to glare source intensity.

Similarly, it has been shown that a number of glare sources add linearly to the effective disability. This simple linear relationship would not hold if factors other than straylight caused disability glare. Furthermore, if a glare source is projected on a blind area of the retina, such as the blind spot, disability glare occurs, again confirming the straylight hypothesis. As stated above, equation 1 holds only for values of  $\theta$  between  $1^\circ$  and  $30^\circ$ . For angles smaller than  $1^\circ$ , it is likely that neural effects are present, but it is safe to assume that beyond  $1^\circ$ , optics dominates.

As described by Vos<sup>3</sup>, for angles of eccentricity greater than  $30^\circ$ , other factors such as age and ocular pigmentation



**Figure 1** An example of induction. The two parts of the square annulus have the same luminance but different brightness due to the effect of the background



**Figure 2** The relationship between veiling luminance and the intensity and eccentricity of a glare source



**Figure 3** The difference between Raleigh and Mie scatter. <http://hyperphysics.phy-astr.gsu.edu>

change the parameters, but the principle of Equation 1 remains. Disability glare can be thought of as an optical rather than neurological phenomenon

Recent studies have established that in the normal eye, the cornea, the crystalline lens and the fundus account for veiling luminance.<sup>3</sup> The aqueous and the vitreous chambers are regarded as optically empty by comparison. The relative contribution of the cornea, lens and fundus are found to be approximately equal.<sup>3</sup>

The effect of age, long recognised as important, was quantified by van den Berg.<sup>4</sup> As might be expected there is a large inter-individual spread due mainly to pigment differences. For ages under 35 the effects are of the order of 6 per cent compared with a perfectly uniform media which is negligible when compared with the spread, but beyond 70 the effects are much larger and in many subjects approach 200 per cent.

**Disability glare in the abnormal eye**

If a patient reports problems of glare it is then appropriate to assume that they suffer from increased intraocular light scatter?

Glare is a complicated problem and as a result, patients' descriptions of the phenomenon are frequently confused and confusing. Conventional measures of visual performance such as visual acuity are often insensitive to the subtle changes in the ocular media during early cataract or following many ophthalmic procedures. Excellent visual acuity is frequently achieved after cataract and many types of corneal surgery, but despite having good VA, many patients complain that their vision is compromised by flare and high sensitivity to bright lights.

These observations are particularly common at night when the problem is exacerbated by large pupils. From a clinical perspective, the main difficulty is in assessing the severity of the problem. Some patients find relatively minor disturbance to their vision extremely troublesome, whereas others easily tolerate gross effects such as those caused by iridectomy.

The link between cataract and glare has been established since the early days of IOL surgery; Neumann *et al*<sup>5</sup> compared outdoor and indoor visual acuity in pre-surgical cataract patients and used a glare test in an attempt to explain the differences between the two measurements. They found that outdoor visual acuity was more closely predicted from their glare test than by the indoor visual acuity measurement.

Refractive surgery is particularly

associated with haze and glare problems. These have been documented in patients who have had both PRK<sup>6</sup> and Lasik. Frost and Sparrow<sup>7</sup> have shown that UK ophthalmologists rarely use tests other than visual acuity, whereas in the US 60-70 per cent of cataract surgeons use glare tests.<sup>8</sup> Glare and night vision problems were the second most frequent post operative complaint reported by Jabbur *et al*<sup>9</sup> in their survey of dissatisfied refractive surgery patients. The main complaint from 59 per cent of the 161 was blurred distance vision but 43 per cent had glare difficulties.

Problems also arise following corneal surgery. One of the many challenges for the ageing eye is maintaining the integrity of the cornea. Almost 50 per cent of the annual 40,000 or so corneal procedures performed in the US are aimed at treating failure of the corneal endothelium. The procedures may involve total replacement of the cornea, penetrating keratoplasty, or so-called partial thickness procedures, such as deep lamellar endothelial keratoplasty.

Although these operations result in a clear cornea and often with good VA, patients suffer from many clinical and visual complications not least of which is excess sensitivity to bright lights, haloes and disability glare.

It is apparent that these patients, who are increasing in numbers, will offer a particular challenge to the eye professions in the future.

Hence, it is important to identify a test or series of tests that, unlike visual acuity, corroborates the subjective observation of patients and allows the effects to be quantified.

**Evaluating disability glare**

As suggested above, there is always a strong subjective component when discussing glare with patients. The issue of reduced visibility of objects is often compounded by the presence of discomfort, and this applies especially when questionnaires are used to evaluate the problem.

Many studies have found that questionnaires do not predict glare symptoms.<sup>10,11</sup> A further difficulty is the problem of the absence of an exact definition of glare and the fact that observers experience glare in its many forms in myriad circumstances.

Below is a summary of the most commonly used methods for evaluating ocular light scatter and glare.

**Straylight meter - the C-Quant**

The straylight meter, now called the C-Quant is a purpose-designed instrument for evaluating ocular scatter.

The device is the culmination of many years research in the area of ocular light scatter by van den Berg and colleagues.<sup>3,12,13</sup> It is manufactured to a high standard by Oculus Optikgerate, GmbH in Wetzlar, Germany and is available from Birmingham Optical in the UK. The measurements are highly repeatable and take of the order of two minutes per eye. Note that the instrument does not measure disability glare, but provides an index of intraocular light scatter.

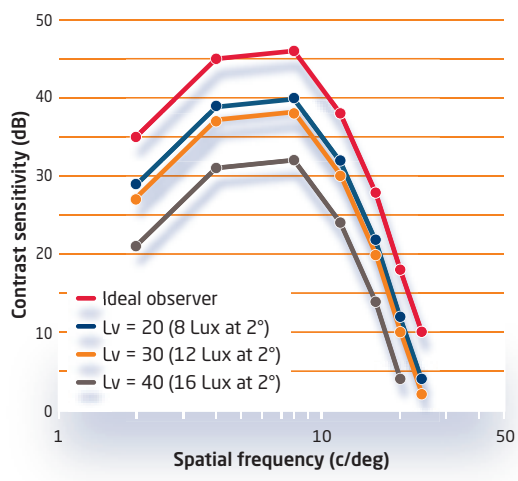
Observers view a central patch of light, which is divided into two halves, surrounded by an annulus of flickering light. The annulus induces flicker in the central patch and the observer is required to choose which half of the central patch flickers most noticeably. This psychometric method works well and patients immediately become familiar with the task. The benefits are that practitioners obtain an objective indication of the extent to which a particular eye is scattering light, along with an indication of the reliability of the measure. A fuller description can be found in van den Berg's 2005 paper.<sup>14</sup> The data correlate with subjective observations<sup>15</sup> and therefore help when referring patients who complain of glare-related problems but who have close-to-normal visual acuity under conventional viewing conditions. Note, however, that the instrument provides an index of light scatter in the eye; it does not measure the visual impact of the scatter.

## Contrast sensitivity

Investigating the effect of intraocular scatter on vision is challenging because it is necessary to introduce a glare source and then compare performance with and without the glare source.

An experiment of this kind was conducted by Paulsson and Sjöstrand<sup>16</sup> who determined contrast sensitivity with and without a glare source. Aslam *et al*<sup>17</sup> presented calculated data, based on the intensity of light encountered when night driving. Their data are illustrated in figure 4. It is apparent that there is an overall reduction in the ability to detect gratings, which is linked to the intensity of the veiling glare as calculated from equation 1. Note that quite modest values of incident illuminance, here at 2° from the line of sight, can markedly reduce sensitivity. These values are based on the light intensity incident on the cornea when night driving.

Due to the band pass shape of the contrast sensitivity function, frequencies to which we are most sensitive and which occur most frequently in the environment are affected most.



**Figure 4** The effects of intraocular scatter in the normal human eye, based on typical values encountered from on-coming headlamps when night driving. Adapted from Aslam *et al* 2007

## Brightness acuity tester (BAT)

This is a simple handheld device with an illuminated hemispherical cup at one end. The patient views a chart through a small aperture in the centre of the hemisphere. Typically, low contrast charts are used such as the Pelli-Robson or Regan charts. The technique is widespread and many experimenters have used it to document disability glare. Magno *et al*<sup>18</sup> investigated improvements in glare after Nd:YAG laser capsulotomy with the device and Wilkins and McPherson<sup>19</sup> showed that the best improvements in vision after Nd:YAG laser were in contrast sensitivity under glare conditions induced by the BAT. Elliott and Bullimore used the technique in monitoring disability glare in cataract patients and suggested it to be highly repeatable.<sup>20</sup> According to Neumann *et al*<sup>21</sup> the BAT scored well when attempting to predict outdoor Snellen acuity.

More recent work has suggested the BAT to have poor sensitivity and validity because it induces pupil meiosis.<sup>22</sup> Other studies on the BAT glare tester have also been rather inconclusive in attempting to predict the effect of bright sunlight on patients' vision.<sup>23-25</sup> Rubin *et al*<sup>26</sup> found the link between visual disability and glare sensitivity with BAT to be at least the satisfactory of a battery of tests. Hence, despite its ease of use and being inexpensive, there are some doubts about the usefulness of the BAT.

## Glare test as an adjunct to existing instruments

Some instruments incorporate a glare source that enables the assessment of disability glare as part of a visual performance test. None can be regarded as gold standard. All are subject to benefits and

limitations along the principles outlined above and of course when well calibrated and in experienced hands, can be useful. The Vistech MCT8000 uses sinusoidal grating targets at different spatial frequencies and an optional glare source is incorporated. The unit is portable and needs little calibration.<sup>20</sup> It is limited by the fact that it does not allow many increments of contrast and uses only a small number of spatial frequencies. A console provides control of target presentation, luminance and glare source position. Neumann *et al*<sup>15</sup> reported the data to be limited in terms of repeatability. Similar units such as the Optech 6500 (Stereo Optical Company Inc. Chicago, IL, USA) are available. The Mesotest II (Oculus Optikgerate, GmbH, Wetzlar, Germany) is performed under low lighting conditions. Measurement conditions provide a simulation of night time driving and this test has been shown to have limited correlation with night driving problems compared with a questionnaire assessment.<sup>27</sup> In a different study the same group regard the test as of limited value compared with the straylight meter which was superior.<sup>28</sup>

## CONCLUDING REMARKS

The literature on disability glare has expanded dramatically in the last decade. The stimulus for this renewed interest is almost certainly the wide range of new surgical techniques available to ophthalmology. When assessing the outcome of a particular procedure, VA is no longer adequate. Glare is frequently one of the complications. The experience of glare is highly subjective, and presents a challenge to ophthalmic practitioners in their attempts to provide advice to patients and to understand how the eye reacts to light scatter. The recent development of objective measures of light ocular scatter, provide a start to the process of understanding this problem. ●

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## MULTIPLE-CHOICE QUESTIONS

### 1 What is meant by the term 'induction'?

- A A change in contrast under different viewing conditions
- B An apparent change in physical luminance related to changes in background lighting
- C Changes in luminance due to after image formation
- D Increases in physical luminance due to increased background lighting

### 2 Which of the following will increase the veiling luminance of a point source?

- A Reducing the angle between line of sight and glare source
- B Increasing the incident illumination
- C Reducing the reflected illumination
- D Reducing glare source intensity

### 3 Which of the following is true?

- A Blue sky is as a result of Mie scatter
- B Cloud's lack of colour is a result of Rayleigh scatter
- C Rayleigh scatter is predominant in the eye
- D Rayleigh scatter is wavelength dependent

### 4 What effect does projection of a glare source onto the blind spot have?

- A No effect
- B Disability glare
- C Discomfort glare
- D Induction

### 5 Which of the following is not contributory to veiling luminance?

- A Cornea
- B Crystalline lens
- C Vitreous
- D Retina

### 6 Which of the following (after Jabbur et al) is the most common complaint after refractive surgery?

- A Poor night vision
- B Glare
- C Blurred distance vision
- D Pain

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● **Dr Ian Murray** is a senior lecturer in the Faculty of Life Sciences, University of Manchester