Determination of Veiling Luminance for Peripheral Visual Objects

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***Abstract*— An experimental set-up that measures location based retinal stray light levels in humans is described. The experiment uses the psychophysical Direct Compensation Method to determine the equivalent veiling luminance on the retinal periphery. The experimental results will be used to adapt the CIE disability glare equations for spatial dependency.**

***Index Terms*— disability glare, flicker, peripheral retina, psychophysics, stray light**

INTRODUCTION

A. Glare

Commonly, people experience glare when looking at oncoming headlights. They sense an actual discomfort or a visual impairment, caused by an inappropriate distribution of light sources or excessive contrast in the field of view. The reduction of visual quality makes glare rating an important aspect of traffic safety assessment. The European Standard (EN 13201-2) defines glare index classes and criterions for the restriction of glare [1].

Generally, glare can be divided into two main types, discomfort glare and disability glare, which differ in their effect on human perception. Discomfort glare is a description of subjective glare. Complaints may be expressed as discomfort, annoyance, fatigue, and pain [2]. Disability glare, which is also known as physiological glare, is glare that impairs vision. It is caused by retinal stray light due to intraocular scattering of the incident light [3]. Stray light veil causes loss of retinal image contrast. The functional effect of retinal stray light on vision makes it an important criterion for the road safety assessment, since the effects of glare sources in the field of view can be quantified by disability glare.

The impairment by glare sources arises from optical scattering of the incident light at the human eye's imperfect optical media, resulting in a broad distribution of stray light on the retina (Fig. 1). The intensity of the stray light veil is used as a measure of glare and is expressed as the equivalent veiling luminance. This is the luminance of a uniform patch of light that changes the contrast threshold by the same amount as the glare source [4]. The equivalent veiling luminance can be quantified using psychophysical measuring concepts.

B. CIE General Disability Glare Equation

We can calculate the stray light distribution by determining the equivalent veiling luminance and measuring the illuminance at the examined eye in the plane perpendicular to the viewing direction. This calculation is based on the General Disability Glare Equation [5], a mathematical model for retinal stray light developed by the CIE. It was created from the experimental data of several stray light studies [3], [6], [7].

Several anatomical and physiological factors can be included in this calculation. These influencing factors are mainly based on properties of the intraocular stray light sources (cornea, lens, translucency of the eye wall, reflection on the retina, see Fig. 2) [3]. The most important factor is the angular distance between the glare source and the visual target. The closer the target is to the glaring light source, the stronger the stray light veil, which is placed over the retinal image of the target. In addition, the translucence of the eye is dependent on the eccentricity of the glare source.The aging of the ocular lens leads to its opacification and pathologically to the formation of a cataract. Thus, incident light is more scattered with age. The pigmentations of the fundus and the eye wall also influence the intraocular light scattering.

C. Issue

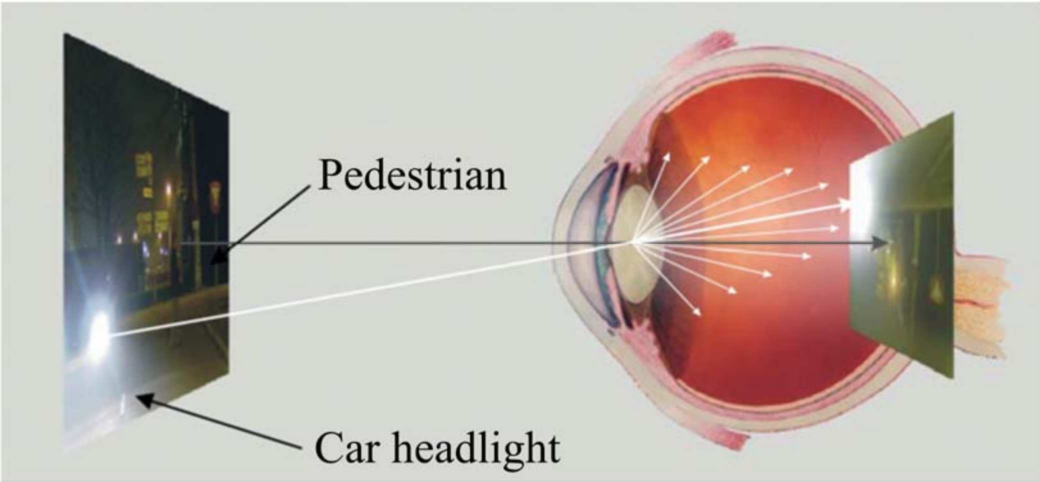

Figure 26. Illustration of retinal stray light with the image of the outside world (left) and its projection on the retina (right). [2]

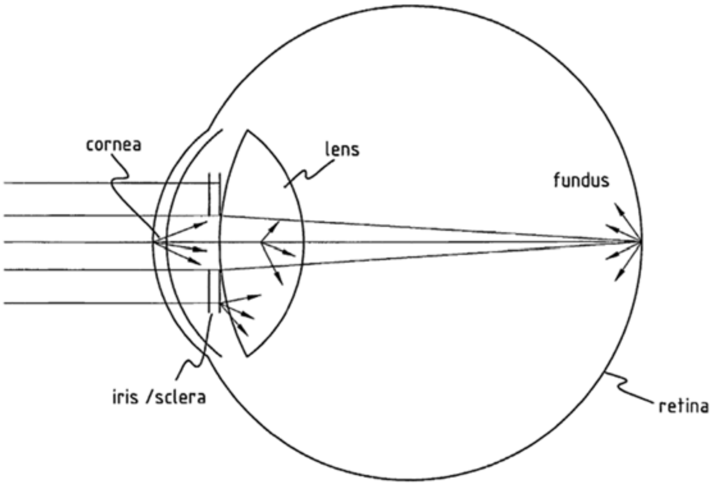

Figure 27. Ocular stray light sources [12]

The CIE General Disability Glare Equation is based only on foveal investigation. Whether and how the distribution of the scattered light for peripheral retinal locations changes is unknown. The first study on extrafoveal stray light originate from Stiles and Crawford in 1937 [8]. They have shown that the common mathematical model describes light scattering on the retina insufficiently, and therefore does not provide sufficient prediction for peripheral visual tasks [9]-[11]. Uchida and Ohno [13] used a visual target, which should be detected in the peripheral visual field, in their investigations on the adaptation field. The perception of the subject was disturbed by a glare source with varying intensities and glare angles. Aim was the measurement of the contrast detection threshold for the estimation of the adaptation state of the observer. The setup was realized by a LCD screen, which represents the target and the background, and an LED glare source. Their results support Stiles and Crawford's statements on the changing distribution of stray light at the retina [8].

However, in most road traffic hazards, the important visual objects, e.g. a pedestrian in dark clothes, located in the peripheral field of vision (on the sidewalk). They are not situated in the line of sight (on the street) and therefore outside central vision.

Nevertheless, only mathematical models of foveal vision are used for safety assessments [1]. To verify their validity, investigations like the approved stray light studies must be carried out with a method adapted to peripheral measurement targets.

RESEARCH HYPOTHESIS

- The equivalent veiling luminance differs for foveal and extrafoveal vision in case of constant angular distance between glare source and target.

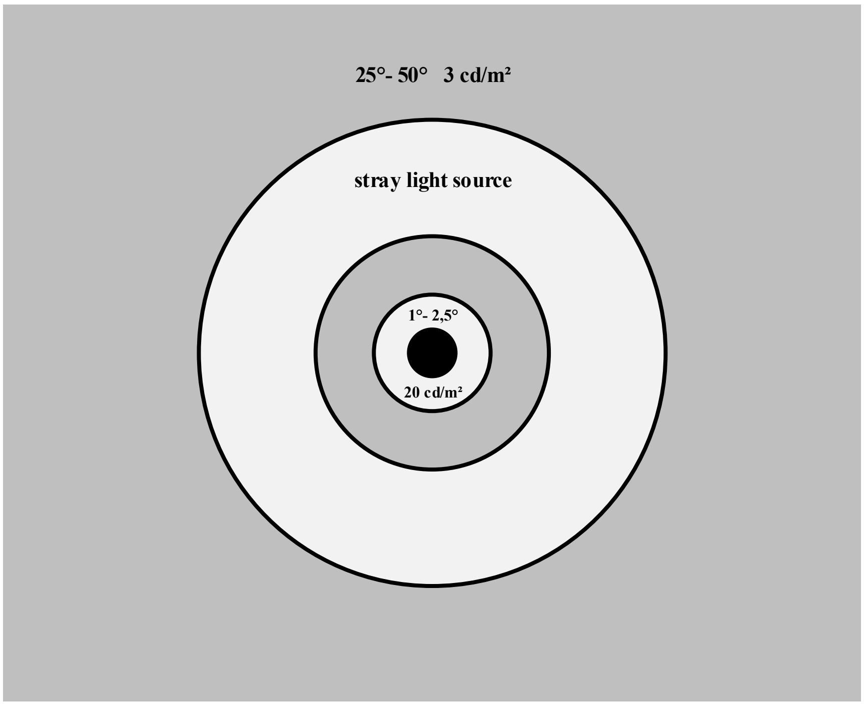

Figure 28. Spatial configuration of the screen from the Direct Compensation Method by van den Berg and Spekreijse (adapted from [14]). In the centre is the dark test spot, which presents an adjustable, antiphase flickering compensation light. It is surrounded by a bright separation ring and a low intensity annulus. The glare source ring flickers with a frequency of 8 Hz.

- The equivalent veiling luminance of an extrafoveal glare source is distributed asymmetrically over the retina.
- With an adaptation of the Direct Compensation Method, introduced by van den Berg and Spekreijse [14], the equivalent veiling luminance of a glare source is determinable for peripheral targets.
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METHOD

A. *Direct Compensation Method*

A Dutch research group under the direction of van den Berg published the Direct Compensation Method, a stray light measuring technique, in 1986 and applied it on many studies to investigate retinal stray light. This method estimates the foveal amount of scatter directly for different glare source eccentricities [14].

The subject monocularly observes a screen with a circular arrangement of fields (Fig. 3). In the centre is the target, a dark test spot, with a 2 degrees' diameter. In the surrounding area is the glare source, that can be presented at four effective distances from the centre (effective radii range from 3.75 to 30 degrees). The glare source flickers with 8 Hz, a frequency that is in the range of maximum flicker sensitivity in human vision. [6, 7]

The incident glare light causes a flicker perception in the dark test spot due to intraocular light scattering. The subject's task is to minimize or clear this flicker perception by adjusting the luminance of the test spot with a dial. The point of flicker disappearance is named compensation point, because the flickering stray light is "compensated" by the test spot luminance. This luminance corresponds directly to the portion of scattered light spread over the foveal retina. The test spot is surrounded by a time-invariant and bright intermediate ring. This suppresses the flicker perception in the area adjacent to the test spot, to ease the performance of the task.

B. *Requirements for The Experimental Setup*

Due to the method and aims of measurement, certain demands should be stated on the setup's design. First, a flickering glare source is required. The flicker frequency of the glare source should be set to be good perceivable. The test spot flicker must be precisely in antiphase to the glare source flicker, so the flicker perception can be cancelled. In addition, the luminance amplitude of the test spot must be adjustable by the subject.

In the original Direct Compensation Method, the test spot is centred on the screen and should be fixed by the subject. By this arrangement, the equivalent veiling luminance can be determined only for the fovea. In the case of a modification for extrafoveal targets, both the source and the test spot must be positioned in the entire visual field to perform

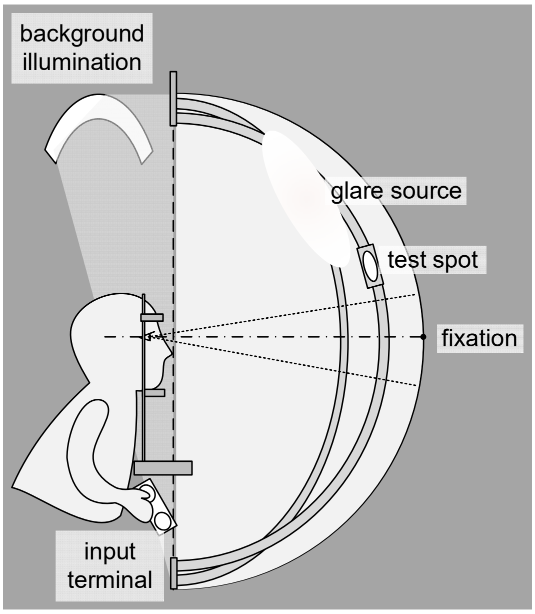

Figure 4. View of the experimental setup. The fixed subject is placed in front of an illuminated half sphere, presenting three visual stimuli: a flickering glare source, an antiphase flickering test spot and a stable fixation point.

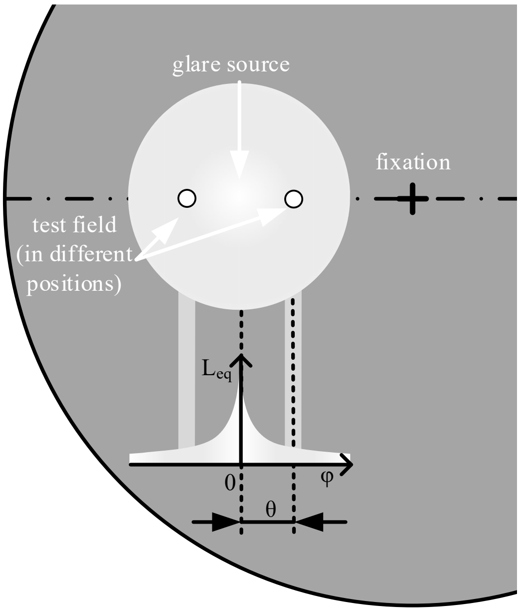

Figure 5. Detail of the setup showing a possible glare source-test spot constellation during a trial. The point-shaped glare source stays fixed with distance φ to the fixation point in the center of the hemisphere. The test spot is positioned on a circle around the glare source with fixed distance θ. The graph shows the profile of equivalent veiling luminance regarding

Figure 6. Fixation object proposed by THALER et al. [15]

investigations in the retinal periphery. In addition, a central fixation point must be installed for the subject. Observation of the fixation should be controlled by an eye-tracking camera for error correction.

C. Stimulus Presentation

The planned experiments will use an adapted setup of the Direct Compensation Method. The subjects are placed in the centre of a white hemisphere with a diameter of 1.5 meter (Fig. 4). Their head is fixed by a chin rest. The subjects are looking at a fixation point. The hemisphere represents the field of view with a constant, uniform adaptation background luminance, so that the subject will adapt to a defined level. The lighting system of the background is mounted above the subject.

Two LED light sources will be presented. Both, test spot and glare source, are mechanically attached to the hemisphere and can be set at any spherical position. They flicker in antiphase and are aligned to the subject. The test spot luminance amplitude can be adjusted by the subject via a control dial. The luminance of the glare source is controlled by the investigator.

D. Fixation and Eye Tracking

The method of measurement necessitates a stable retinal image of the glare source and the test spot and a minimization of fixational eye movements. For that purpose, an eye-catching fixation point should be presented to gain high accuracy. Also, the subject is encouraged to maintain the visual gaze at the centre of the hemisphere. Thaler et al. propose a target shape looking like a combination of a bull's eye and a cross hair for experiments that require a stable fixation (Fig. 6, [15]). For monitoring the fixation stability, the subject's eye movements are controlled by eye tracking.

DATA ACQUISITION

The experiments present different constellations of glare source and test spot positions in the visual field (Fig. 5). During trials the glare source stay fixed and the test spot will be positioned in an orbit around the glare source to “scan” the location-dependent distribution of the retinal stray light veil. The combination of the scanned data allows reconstructing the retinal stray light distribution.

We use a psychophysical method to determine the location-dependent equivalent veiling luminance. The subject’s task is to find the compensation point, the point of vanishing flicker perception at the test spot. It is an absolute threshold. Therefore, threshold matching methods are most suitable for data acquisition. To find the threshold we use the ascending and descending method of limits. In the ascending method, the test spot luminance amplitude is increased from zero to flicker disappearance. In contrast, in the descending method the too high test spot luminance amplitude is reduced to the point of flicker disappearance. Six compensation points are determined in each of the three ascending and descending runs. The thresholds are averaged to determine the equivalent veiling luminance of the experiment.

PLANNING THE TRIALS

After the completion and calibration of the setup a pilot study for verification of the measuring method takes place. After positive results a cross-sectional study is accomplished with glare source-test spot constellations and different subject properties (e.g. age, eye colour, cataract). The data analysis leads to adjustment supplement of the CIE General Disability Glare Equation for local dependency and, therefore, to a mathematical modelling of disability glare in peripheral vision.

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