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DESCRIBING THE LUMINANCE ADAPTATION OF THE HUMAN EYE FOR INHOMOGENEOUS SCENES VIA SPHERICAL MIRROR PROJECTION AND THE LUMINANCE OF SUBJECTIVE BLACK

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Abstract

Baseline investigations describing luminance adaptation, color perception or glare rating were made a lot.
Many attempts have been made to describe and calculate luminance adaptation of the human eye. Nevertheless until now there is no exact and common model to calculate e.g. luminance adaptation for a given scene.
Lowry, Haubner or Rehder made the first steps in homogeneous surroundings with measuring the luminance of subjective black for a given luminance.
To know a person totally adapted to a surrounding they illuminated a hemisphere with a filament lamp rim. In the center of this hemisphere there was a circular dimmable light source with which the luminance of subjective black could be measured. Their experimental setup had some limitations in describing luminance of subjective black in inhomogeneous surroundings.To fill this gap spherical mirror projection might be useful.
Using a digital projector and a spherical mirror, it is possible to generate homogenous as well as inhomogeneous scenes within a hemisphere. Furthermore, the impact of structured scenes of the luminance of subjective black can be observed.

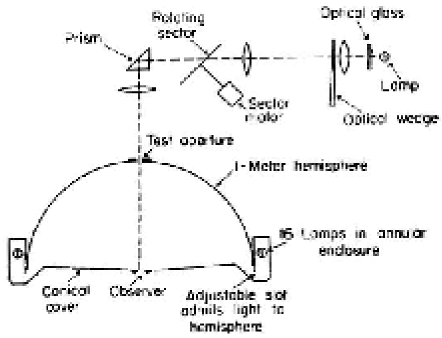
Keywords: luminance adaptation, spherical mirror projection, equivalent veiling luminance, luminance of subjective black

1.INTRODUCTION

During the last decades there have been many attempts to improve the technology of light distribution according to human requirements. New light sources e.g. LED or OLED's are nowadays on the rise for indoor as well as outdoor lighting.
Simultaneously to this development, former quality criteria e.g. for human vision, which were based on filament or fluorescent lamps, have to be renewed. Describing all functions of human visual apparatus in context to several given situations and luminance distributions is a goal of researches around the world. An old one but still not totally solved problem is describing and calculating the luminance adaptation of the human eye for inhomogeneous surroundings [1].
Lots of model's were made for mesopic and photopic vision using similar methods and experimental conditions. Summing up several approaches and combining them with new technical methods the following paper will show an approach for describing the luminance adaptation of the human eye by measuring the luminance of subjective black for inhomogeneous luminance distributions.

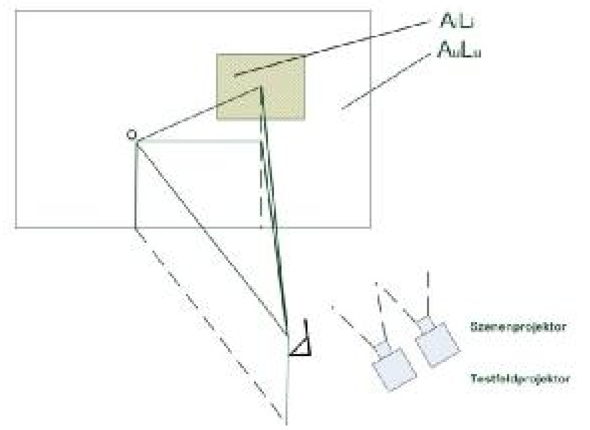
2.HISTORY

Scientists studying the luminance adaptation of the human eye needed similar conditions for their experimental setups.
Lowry, Haubner as well as Rehder just to mention a few, needed a homogeneous surrounding for their studies. To realize this requirement they used a Dome and an annulus of filament lamps at the rim of this Dome (see Graphic 1 below). In this way homogeneous background luminances up to 1000cd/m² were easily possible [2][3][4].



Graphic 1: experimental setup Lowry

As one can see, in the center of this dome was the test field which subtended an angle of 22' at the eye of the observer [2]. The luminance of this field could be reduced by the observer until it just disappears for a given surrounding (luminance of subjective black). Lowry did his research within homogeneous surrounds and found a way to forecast adaptation luminance by knowing the luminance of subjective black. For inhomogeneous surroundings he tried to find an approach to combine data measured within both kinds of situations.
Thiele and Gall went another way without a dome (see Graphic 2). Observers in their setup had to adapt to a relatively high luminance distribution. After doing this they switched this luminance with a lower luminance distribution and measured the time (tE) to solve a given visual task [5].
Furthermore they tried to find out whether there is an influence of visual adaptation within different positions in the visual field or not.



Graphic 2: experimental setup Thiele, Gall

After their research they came to the conclusion that a general statement of the state of adaptation for foveal adaptation is hardly possible.

In 1987 Adrian used a dome as an adapting field similar to Lowry. In contrast he was able to change the size and luminance of an inner visual field between the test spot and its surrounding. It was possible to remove a center part of the dome and replace it with translucent circular part of the dome which was illuminated from the back. In summary he postulated, a visual field of the same average luminance can produce different adaptation levels and there is no simple relation between the luminance of a field size of 20 degrees and adaptation luminance. [8].

3.APPROACH AND PROCEDURE

Although the described experimental setups had their benefits, they all are limited in one case. It is not possible to do research in a homogeneous and an inhomogeneous surround without going to considerable length in time in mechanical alterations. On this level, research in Ilmenau begins. The idea was to combine psychophysical methods as well as former experimental setups and to improve everything by using a technique called" spherical mirror projection". This principle was mainly impelled by Paul Bourke [8] and is well known in the gaming industry.

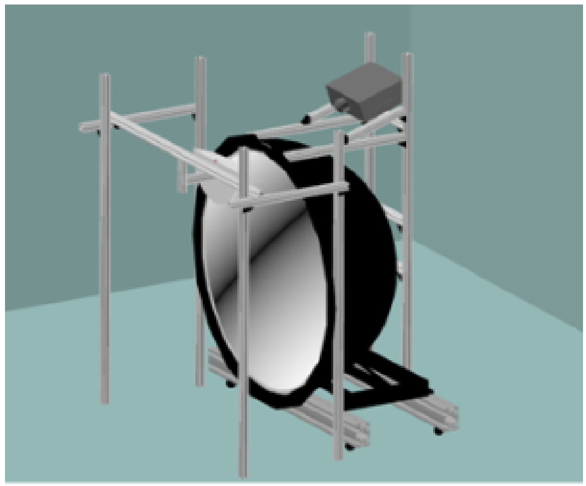
The experimental setup shown in Graphic 3 consists of a full dome (150 cm in diameter) a spherical mirror a digital projector (6000 lumens) and a special software (for the warping algorithm) driven by a normal PC.

It is now possible to investigate the effect of homogeneous and accurately defined, time stabilized inhomogeneous surroundings, on the observer. Time needed to switch between several luminance distributions is minimized and just a simple mouse-click away.

Furthermore there are luminances up to 300cd/m² possible on the inside of the dome.

As mentioned in the introduction there are still some research questions unacknowledged.

How can luminance adaptation be determined if the visual field is inhomogeneous?



Graphic 3: experimental setup Ilmenau

Is the average luminance calculated over a field of view of 40 degrees precise enough to give a statement about the state of adaptation?

To investigate the effect of different surroundings on the human luminance adaptation the approach of Lowry's studies was used. Measuring the luminance of subjective black is one way to get information whether the adaptation level of a person has changed or not. The luminance of subjective black is the point where a luminance e.g. of a test spot appears black within a given surround. First of all an observer is placed in front of the dome and sees only homogeneous surrounds.

For these surrounds he or she has to reduce the luminance of a test field in the center of the dome which subtends an angle of 30' (at the observer's eye) until it just disappears flashing. Afterwards this test is being repeated but the surrounds will be inhomogeneous.

Aim of this method is to find that equivalent adaptation luminance which produces the same subjective black in a homogeneous surround.

3.1.HOMOGENEOUS SURROUNDS

Starting with homogeneous surrounds an observer took place in front of the dome. The head's position was fixed with a chin rest and the test spot luminance could be adjusted by a remote control. For each of four surrounds, 3cd/m² up to 230cd/m², all test persons had to adjust the luminance of subjective black ten times.

Results compared to Lowry and Haubner showed similar effects and run of the curves. Differences are explained in [10].

With knowledge of the run of the curve it is now possible to calculate what luminance of subjective black equals the luminance of a homogeneous surround. This is necessary for tests in inhomogeneous surrounds as described before.

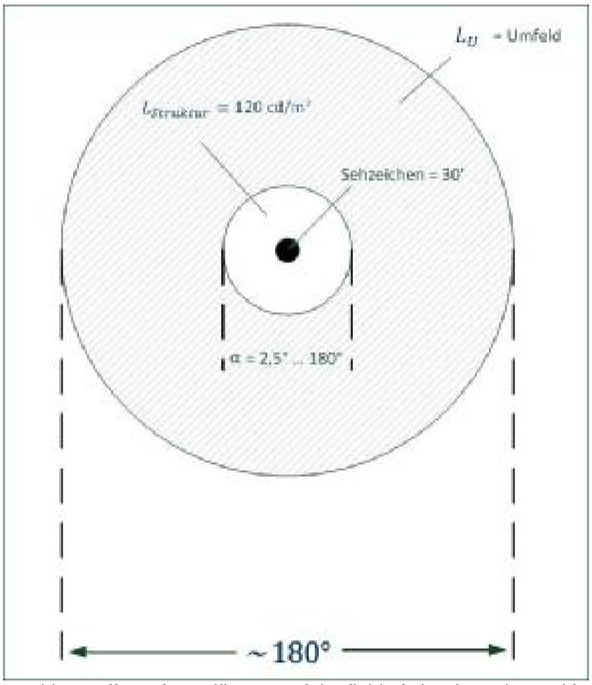
3.2.INHOMOGENEOUS SURROUNDS

In everyday life the luminance distributions in the human field of view change permanently. Until now there is no scientific approved model to forecast or calculate the adaptation luminance for inhomogeneous scenes. Starting with simple structures e.g. circles, rectangles or annuluses' [see.10 P.8f] is the first step to handle the problem of various surroundings and their effect to the human visual apparatus. The following steps will consist of more detailed structures up to abstracted bureau scenes in grayscales.

To prove if the average luminance of a half space in front of an observer (see [9]) is exact enough for describing the adaptation level, simple circular structures were used. Referring to Baer a field of view of about ± 20° can be seen as adaptation dominating [7].

The second step is based on Adrian [11]. This time the field luminance is kept constant but the field’s size changes step by step. As shown in Graphic 4 the field luminance is kept at 120cd/m².

The field of view is varied from 2,5° up to 180°.



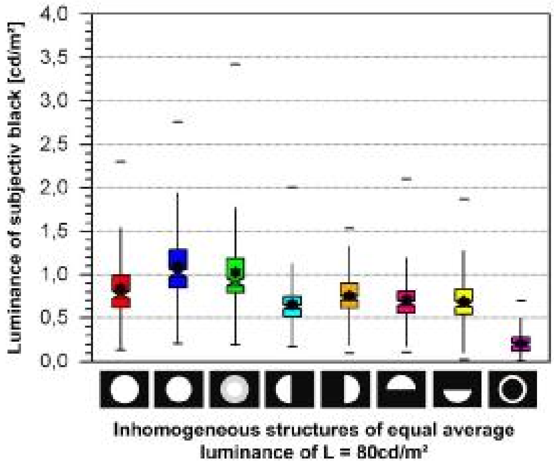
Graphic 4: Effect of specific parts of the field of view based on Adrian 1968/69

4.FIRST RESULTS

All structures shown in Graphic 5 were presented in the center of the dome within a field size of ± 20° having the same average luminance. These structures ranged (left to right) from a circle of± 20°, a circle ± 15°, an inner circle of ± 10° combined with a annulus Ring, four semicircles of different orientation and an annulus Ring between ± 20° and ± 15°.

If the averaged luminance within a defined field of view as written in [7] is suitable to describe a human’s adaptation level, the luminance of subjective black must be the same for all structures. In that case the influence of peripheral luminances is neglected and set to a luminance of approximately 0 cd/m².

Further influence of peripheral luminance distributions will be discussed in following studies.



Graphic 5: first results of defined inhomogeneous structures

Results obtained show a statistical significant variation in the luminance of subjective black although the average luminance is equal for all structures. Considering the semicircle structures, measured values show no significant difference in the position of each structure. Comparing the results of e.g. a circle of± 20° and an annulus Ring between ± 20° and ± 15° the luminance of subjective black of the Ring is significantly lower than the one of the circle. One reason can be seen in the different contrast of the structures found directly around the test spot. Another one in the different equivalent veiling luminance generated by each structure.

As mentioned above the next step will be a change in the field’s (circle structure) size while the field luminance is kept constant. Furthermore it is of interest how the luminance of subjective black (and later on the adaptation luminance) follows the luminance increase of a defined structure in the field of view.

Both aspects will be discussed during the presentation in Bulgaria because the field data for this part wasn’t finished yet.

5.DISCUSSION CONCLUSION

Concluding the explained experimental setup and furthermore results obtained with it, some limitations have to be mentioned.

The luminance range used is limited to max value of 300cd/m². Experiments were made with max 230cd/m² which is at a lower level of photopic vision. Decrease of luminous flux of the projector lamps can be compensated with the software used for the created images.

Combining all results during my investigations it will be possible to get a closer “look” into the mechanism of the human visual system and the adaptation level a person is adapted to within an inhomogeneous luminance distribution.

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