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ABSTRACT BOOKLET

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CIE Workshop on a New Vision of Visibility for Roadway Lighting

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FOREWORD

The world has changed since the introduction of electric lighting. 100 years ago climate change, waste of energy, influence on the circadian rhythm through light during the night, different needs of the elderly, death of insects, loss of the dark night sky were not thought about. Today all these topics are of global interest. As engineers, physicians, architects and psychologists we are responsible for our doing. As lighting scientists and designers, we have a special responsibility for the using of electric light in the world.

Within the workshop we go back to the beginning of electric light. We will pose questions such as: Why do we illuminate our roads? How much light is necessary for a good safety? Is the increase of installed electric power for road lighting necessary? Are the criteria for light quality complete and correct?

Of course, we have an impression of good light. For instance, all road users should be able to see objects on the road and be visible to each other, good visibility conditions are assumed for this. However, are we using the right tools to achieve this aim?

Different methods have been developed for the description of visibility conditions. Unfortunately, these methods have never been used in practical lighting design processes, often due to the omission of some variables relevant to the models. For example, measurement methods for the road surface reflection, optimization tools for the reflector or lens design of luminaires, consideration for luminaries with adjustable light distribution and lack of imaging luminance measurement systems.

Now however, there are new ways of lighting and new measurement methods for light, with LED based luminaires and imaging luminance measurement systems in use. Given these, this workshop will analyse the potential of the different visibility concepts. In addition, the area where scientific creativeness overlaps the uptake of new technologies both in pragmatic and economic ways will be discussed.

The result of the workshop will be used to inform the direction of future work of the CIE on this topic.

I am very glad that you participate in our discussion about these subjects. I am convinced that our findings will help to improve our safety.

Have nice and fruitful days in Berlin.

Stephan Völker, Chair of the Department of Lighting Engineering at Technische Universität Berlin

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HUNDRED YEAR ROAD LIGHTING RESEARCH

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Abstract

This presentation will describe the road lighting research approaches of the past 100 years. This "tour" through the past century may give guidance for road lighting research today: by learning from mistakes made in the past, but also by studying approaches which are forgotten because they were not very relevant for the circumstances of that time but could be relevant for the changed circumstances of today.

Serious road lighting research started during the early phases of the changeover period from gas lighting into electrical lighting around the nineteen-twenties. In this period motorised traffic became a regular means of transport which, in turn, increased the demand for adequate traffic capacity also during the dark hours. Research was aimed at the visibility of objects on lighted streets. Waldram in the UK defined the luminance concept of road lighting.

Only after the second world war, with the arrival of high-speed road-users and the construction of relatively comfortable motorways, the scope of road lighting research was adapted to include visual comfort aspects.

With traffic accidents becoming more severe and more frequent, statistical analysis of accident data received much attention in the sixties of that century. Attempts were being made to find correlations between the number of accidents and road lighting quality.

In the seventies, providing anticipation possibilities to car drivers gets much attention. As a consequence, a more or less structural analysis of the driving task starts playing an important role in research on road lighting.

Where in the early eighteenth century the objective of lighting streets was a reduction of crime in the streets after dark, this objective has until the late nineteen-seventies never been a serious subject of investigation. With the cuts in street lighting immediately following the energy crisis of 1973, the aspect of security connected with lighting in residential areas gets much attention in street lighting research. For the first time, the needs of the pedestrian were seriously investigated.

The last ten years of the past century traffic congestion gradually increases, and road lighting research moves towards the aspect of facilitating traffic flow. Here no longer only lighting but also traffic guidance and signalisation start playing a role.

The selection of the various studies that will be dealt with in this presentation is done to give a typical representation of the various periods described above.

IMPACT OF LIGHTING ON SAFETY

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Abstract

Lighting has long been shown to have an impact on roadway safety. Analyses have determined that the addition of lighting to a roadway can have a positive impact on the reduction of vehicle crashes. Historically, these crash reductions have been as high as 50 % however as the science of crash analysis has evolved, some of these statistics have been shown to be weak. The other issue is that while correlations to crash reduction have been established very little causative impacts have been determined. This discussion is a review of historical safety analyses and current approaches to lighting safety analyses. The final discussion considers the link of lighting to driver safety through naturalistic driver studies and lighting analyses.

ROAD SAFETY AT NIGHT: THE VISUAL CHALLENGES, LIGHTING ISSUES AND IMPROVING VISIBILITY

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Abstract

Night driving is dangerous. Adjusted for distances driven, fatality rates at night are 2-4x higher than for the daytime, with night pedestrian fatality rates being up to 7x higher than in the day; the severity of injuries from night crashes is also 2x that for the day. Reduced lighting and poor visibility are associated with these high night crash rates, independent of other factors that vary between day and night driving. Importantly, the visual environment when driving at night is particularly challenging, as the low luminance conditions alter many aspects of visual function, in addition to the challenges presented from the fluctuating light levels typically encountered.

This presentation will provide an overview of our research work on the impact of vision on night driving ability, highlighting research undertaken on a unique closed road facility, which provides an ideal environment in which to conduct such investigations. Research presented will discuss the impact of vision on night driving across a range of young and older populations, both with and without vision impairment. Findings will also be presented from studies assessing the effect of street lighting levels on hazard detection, as well as research on improving the visibility and hence safety of vulnerable road users, such as pedestrians and cyclists.

ROAD LIGHTING FOR PEDESTRIANS: DESIGN GUIDANCE PAST, PRESENT AND FUTURE

Steve Fotios
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Abstract

When lighting is designed in subsidiary roads, the target users are assumed to be pedestrians, and guidance tends to be given primarily in terms of average illuminance and either a uniformity or minimum illuminance. The empirical basis for these recommendations is however somewhat limited, where it exists at all, and in some cases may simply be a case of requirements lower than those for motorists. This is not an acceptable situation. When agents for external factors such as energy use, sky glow, and non-visual effects lobby for lower light levels we need to know how such action would impact upon the visual needs of pedestrians. Until recently, those data were not available. In the past few years there has been an increase in research targeting pedestrians: CIE technical committee 4-51 is collating these data to promote consideration of empirical evidence when lighting criteria are recommended.

QUANTIFYING ECONOMIC BENEFITS AND COSTS OF ROADWAY LIGHTING BASED ON SAFETY-RELATED VISIBILITY CHARACTERISTICS

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Abstract

1. Motivation

To the extent that visibility concepts such as the relative visual performance (RVP) model or visibility level (VL) can predict safety-relevant responses in the nighttime driving environment such as hazard detection distances or response times, it is reasonable to expect, and indeed evidence suggests, that these concepts have applicability to predicting the driving safety benefits associated with roadway lighting. These benefits can be quantified and even monetized in terms of the avoided costs of crashes ranging in severity. Further, roadway lighting has specific and discrete costs associated with purchasing, installing, operating and maintaining lighting systems.

2. Methods

An approach to economic benefit/cost quantification of roadway lighting will be described in the proposed workshop presentation. Once the nighttime crash reduction of a particular roadway lighting configuration is determined (using, for the purposes of the current presentation, a *transfer function* linking improvements in visibility from lighting with nighttime crash reductions), the economic impacts in terms of lighting system costs and in terms of avoided crashes can be estimated. Importantly, the benefits will depend not only upon the specific roadway configuration and type, but also on the overall traffic volume expected through the roadway location being evaluated. This traffic-volume dependence on crashes, however, is not linear and cannot be quantified using crash rate ratios that assume the number of crashes is proportional to either nighttime or overall traffic volume. Using this approach it is possible to determine the minimum traffic volume for which roadway lighting could be expected to provide a net benefit in terms of avoided crash costs, in comparison to the costs associated with the purchase, installation, operation and maintenance of roadway lighting.

3. Results

Analyses of roadway intersection lighting for rural unsignalized and urban signalized intersections were made, using crash data from the U.S. state of Minnesota and based on existing lighting practices in that state. Intersection lighting at urban intersections tends to be more costly than at rural intersections because in urban locations lighting is more likely to be continuous, whereas at a rural intersection only one or two luminaires are usually installed at the junction along otherwise unlighted roads. Controlling for other factors such as posted speed limit, percentage of heavy trucks, and median and shoulder types, lighting as typically practiced is associated with larger crash reductions at urban signalized intersections than at rural intersections, possibly because rural intersection lighting at the junction only does not help drivers judge the position and speed of vehicles approaching, but not yet at, the intersection. The threshold traffic volume for the intersection's major roadway above which lighting results in a net benefit is about 1800 vehicles per day at rural unsignalized intersections and about 2500 vehicles per day at urban signalized intersections, based on economic costs of crashes published by the U.S. Department of Transportation.

4. Conclusions

The approach described here can be applied to other situations. For example, increasing the light levels from rural intersection lighting during peak nighttime traffic volumes and decreasing them during periods of reduced traffic use can result in similar lighting costs but substantially increased nighttime crash reductions, doubling the benefit-cost ratio. Using a semi-continuous lighting installation of several luminaires along intersecting rural roads can also result in increased safety benefits, larger than the proportional increases in cost. Importantly, basing economic analyses on visibility characteristics linked to safety allows transport agencies to compare lighting alternatives in the design phase rather than assessing the impacts of such alternatives years after their installation.

COST-BENEFIT ANALYSIS OF USING VISIBILITY CONCEPTS

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Abstract

Different methods have been developed for the description of visibility conditions. Unfortunately, these methods have never been used in the practical lighting design process. There are different reasons, among other things e.g. missing simple measurement methods for road reflection, missing optimization tools for the reflector or lens design, missing luminaries with adjustable light distribution and missing affordable image luminance measurement methods.

Currently, with the LED and disposable image luminance measurement, the necessary preconditions are given. The presentation is dealing with benefits and costs of lighting design based on visibility concepts. Do we have the technical preconditions? Which additional expenses are necessary for the luminaires? Which software tools do we need for calculation of an optimal luminance intensity? How can we estimate the reflectance of the road and the surrounding during the design process? Is it practically realizable?

GENERALIZATION AND VALIDATION OF VISIBILITY CONCEPTS/ IS VISIBILITY A GOOD COUNTER OF QUALITY OF LIGHT?

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Abstract

Why do we illuminate our roads? All road users should be able to see objects on the road and should be seen by others. Good visibility conditions are the base for safe traffic. It sounds logical that we use Visibility as a criterion for road safety. In the currently lighting design process the average illuminance or average luminance of the roads are calculated, but not Visibility. What are reasons for this?

A lot of designers, but also scientists claim: The visibility concept is not usable, because it is too complicated, makes a lot of hypotheses and doesn’t supply a reliable prediction of visibility.

Some of the points are addressed by the presentations planned. By means of investigation of eye-tracking we could show, that not every visible object (contrast above the threshold contrast) will be detected. Only objects in the area of interest are relevant. The area of interest is a dynamic value depending on driven speed, road construction, expected objects on the road, driven trajectory and further parameters. If we want to describe the light quality of road lighting, it makes sense to concentrate on the visibility of objects on the road at dangerous distances. Dangerous distances are distances where it is improbable to stop the car.

Another point for using the visibility concepts is to define the ‘visibility of the critical object type’. The purpose of lighting is to prevent crashes with pedestrian and cyclists. So, it is logical to concentrate on objects like people. But which reflectance should be used? The proposal 'Use the maximum of the well-known Goldman curve’ is one way, but is it really a good indicator for overall safety? The model of Hentschel uses every possible reflectance of clothing. The presentation will discuss this.

In an inhomogeneous lighting situation, you will find a lot of contrasts in a luminance image picture. Which contrast is relevant for the calculation of Visibility? Also, some different starting points will be illuminated.

There are a lot of further influencing parameters which must be discussed.

The most investigations have been carried out for military and for tunnel lighting. Which of the results can be transferred for the evaluation of road lighting? Where do we have comparable conditions and where not?

DETERMINATION OF ROAD LIGHTING AUTOMATION SCENARIOS BASED ON VISIBILITY CALCULATIONS

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Abstract

Istanbul Technical University (ITU) and Istanbul IT and Smart City Technologies Inc. (ISBAK), developing a common project, with the support of Ministry of Science Industry and Technology, established a test road in Istanbul, ITU Ayazaga Campus, where different road conditions and scenarios can be practiced, in order to assess and measure the visual performance of drivers.

The visual performance of the drivers are studied in terms of visibility level (VL) calculations of the critical objects on the test road. Therefore, a 20 cm x 20 cm flat square object with a Lambertian surface is used in this study. For the critical object with a reflectance of 0,20 (as given in CIE recommendations) the minimum calculated VL is 2,22. Theoretically, it is stated that for VL's higher than 1,0, the object starts to appear as a silhouette on the road surface background. In order to study the visual performance of drivers in a wider range of VL's, objects with higher reflectances are required. Taking precalculations on the test road into consideration, the reflectances of the critical objects were selected as 0,20, 0,30, 0,40 and 0,50. Thus, VL values between 0 and 11 were obtained. When determining the background luminance used in the VL calculations, there are different approaches, such as choosing the background luminance on the right and left sides of the object, the background luminance on the four sides, or the region with the greatest luminance difference. In this study, back ground luminance on the four sides of the object were evaluated.

Measurement photographs that are taken for a fixed observer at 60 meters, are evaluated by 30 subjects (average age 30) in the laboratory. The intention is to find out which VL values of critical objects can easily be seen and which VL values are hard to see. 121 scenes with different object reflectances on different road lighting classes are evaluated by each subject. According to the results, it is evident that critical objects with a VL of 7 or greater can be seen 100 % of the subjects in all scenarios. VL's greater than 3,5 can be seen by 90 % and VL's greater than 2,5 can be seen by 80 %.

According to EN13201-3 and CIE 140, the observer position is fixed for luminance measurements and is 60 meters from the first lighting pole in the measurement area. However, in real conditions, the drivers move at a certain speed and one of the parameters taken into account when deciding the lighting class in road lighting automation applications is vehicle speed. It is necessary to provide a luminance level that drivers can see the obstacles from a safe stopping distance. When a lighting automation system is applied, the luminous flux of the luminaires can be adjusted and the lighting class of the road can be changed between M1 and M6 classes according EN 13201-1 while the vehicles are moving at a certain speed on the road. For this reason, the VL values are calculated for the moving observers from safe stopping distance, to show how changing the road surface luminance will change the VL of the critical objects, placed in the calculation area, while the vehicle speed is not changed.

When vehicles are moving at 90 km/h, which can be considered as the legal speed limit for M2 class roads, if the luminance is reduced from 1,5 cd/m^2 to 1 cd/m^2 (road class is changed from M2 to M3) and then from 1 cd/m^2 to 0,75 cd/m^2 (road class is changed from M3 to M4) the visual performance of the drivers should not be degraded. In order to reveal the change in the visual performance of the drivers under different road lighting classes, object and background luminances are measured under the lighting quality criteria appropriate to the classes M2, M3 and M4, from 78 meters, which is the calculated value of safe stopping distance according to CIE 88 and for dry road conditions, for the vehicle speed of 90 km/h. Similarly object and background luminances are measured under the lighting classes M3, M4 and M5, from 50 meters which is the calculated value of safe stopping distance for the vehicle speed of 70 km/h. VL's are calculated from these object and background luminances. Reflactance of the critical object is taken as 0,20 this time, because probability to see higher reflectances on real road conditions is very low according to Smith's curve. Calculated VL's are

greater than 2,5 for all scenarios and supposed to be seen with a probability of 80 %. In other words, the variation of VL values in the calculation area for different lighting classes is within acceptable limits (80 % is taken acceptable), which means that changing the road lighting class up to two levels does not change the visual performance dramatically while the drivers are traveling at a constant speed. In this way, it is possible to reduce the road surface luminances at times when the time dependent parameters such as traffic intensity, ambient luminosity and navigational task is changing but the vehicle speeds are not reducing.

The first pilot application was established in 500 meters of Cendere Street in Istanbul, to realize these scenarios. According to the average speed of the passing vehicles, traffic density, road and ambient conditions, the lighting classes for Cendere Street will be changed between M2 and M5. As a result of the calculations, it is estimated that about 58 %–64 % energy savings in the summer months and 62 %–63 % in the winter months can be achieved by changing the road lighting classes at different time periods during the night.

In this presentation, we will try to summarize the data obtained from the studies we have carried out for about two years. In addition, we aim to discuss unclear parameters in the determination of road lighting criteria, according to VL principle.

VISUAL PERFORMANCE MODELING AND ROADWAY SAFETY AT NIGHT

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Abstract

1. Motivation

Current metrics for specifying roadway lighting include the luminance of, and the illuminance on, the roadway. In essence, these quantify the horizontal illumination upon the plane of the paved roadway surface, and not the interplay among horizontal and vertical illumination levels as they might influence the contrast of three-dimensional objects along the road. Metrics based on the small target visibility (STV) levels provided by lighting for standardized small targets were incorporated into recommended practices for roadway lighting in North America for three decades, but have recently been withdrawn, in part because they ignored illumination from vehicle headlights, an important component of the lighted roadway environment at night. The motivation of the proposed workshop presentation is to introduce a methodology for characterizing roadway lighting in combination with vehicle lighting in terms of the relative visual performance (RVP) as a tool for predicting the potential benefits in terms of nighttime crash reduction, especially with the ongoing proliferation of solid-state lighting technologies that could result in very different physical configurations for road lighting from conventional forms. Like concepts such as visibility level (VL), the RVP model characterizes the speed and accuracy of visual processing as a function of light level, contrast and size of the visual stimulus, as well as the age of the observer.

2. Methods

First, the psychophysical relationship between values of RVP and applied visual outcomes such as reaction times and detection/identification distances under conditions of nighttime roadway illumination are established. Second, the RVP model is used in several different representative roadway intersection lighting scenarios (e.g., urban versus rural, signalized versus unsignalized) to identify the incremental visual benefit of roadway illumination compared to intersections without roadway lighting. Importantly, these analyses incorporate illumination from vehicle headlights as a source of useful illumination as well as a potential source of disability glare along the roadway. Third, the figures of merit from the aforementioned RVP analyses were compared to statistical nighttime crash reduction models based on the presence or absence of roadway intersection lighting; these models also included many other safety-related factors such as the traffic volume, posted speed limit, number of heavy trucks, and median/shoulder types in order to isolate, as much as possible the impacts of lighting alone. The nighttime crash models for different roadway intersection types were also compared to metrics such as horizontal illuminance and STV.

3. Results

None of the metrics that are presently or have recently been incorporated into roadway lighting recommendations result in satisfactory correlations with nighttime crash reductions, calling into question their value as useful characterizations of roadway lighting for safety. In comparison, quantities for estimating the visual performance benefits of roadway lighting using RVP were strongly correlated with modelled nighttime crash reductions.

4. Conclusions

The analyses presented here support the notion that visual performance quantities based on RVP can be used to develop meaningful predictions about the safety benefit of roadway lighting in terms of nighttime crashes. It is essential that metrics that take into account the contrast of potential hazards along the roadway be used, and that interactions with vehicle lighting as a source of illumination and of disability glare be considered. Estimates of nighttime crash reductions associated with lighting or with any other safety system must, to the extent possible, include as many factors as possible related to the characteristics of the roadway environment and the traffic conditions as possible. The results from these analyses can be used to explore alternative approaches to roadway illumination that take

into account visual responses under different light levels and lighting geometries in order to investigate how lighting can be designed to more effectively control energy waste and light pollution.

DISTRIBUTION ANALYSIS OF DETECTION DISTANCES: A NEW APPROACH TO ANALYZE NIGHTTIME ROADWAY VISIBILITY

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Abstract

In nighttime visibility studies, detection distance is commonly used as a measure of visual performance. Such studies focus of the mean detection distance. The mean detection distances do not tell the complete story and by using means we are assuming that the detection distance data is normally distributed, which it is not. These problems can avoided by studying the distribution of detection distances. This paper focuses on examining the detection distance distribution of four objects (standard roadway visibility target, static pedestrian, moving pedestrian and bicycle). Weibull function were fit to the detection distance distribution data to analyze and understand the trends of the parameters. Presence of roadway lighting and motion tend to result in higher scale parameter values. Higher scale parameter values are usually associated with increase in visibility. Scale parameter also is affected by the mean detection distance. Shape parameter trends could not be clearly understood as it might depend upon multiple factors.

A NEW ITALIAN EXPERIMENTAL STANDARD COMPARES THE PERFORMANCE OF ROAD LIGHTING INSTALLATIONS USING THE SMALL TARGET VISIBILITY CONCEPT

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Abstract

1. Motivation, specific objective

The Small Target Visibility (STV) approach is a well-known methodology for defining the lighting level of a road lighting installation able to guarantee a given degree of motorized traffic safety.

STV is a mathematical model of vision obtained considering the results of several experimental investigations about the threshold level, i.e. the contrast limit at with the surface of an object is just visible, with a given probability, respect to its background, lighted to obtain a given luminance.

In road lighting the STV approach can be applied defining the following parameters:

- dimension of a reference target;
- its reflectance;
- position and number of the target on the road surface;
- a metric to correlate the number of visible targets and their contrast to road safety.

All points need some conventional choices according to the type and volume of motorized traffic.

STV was first adopted in USA as an alternative design method, but the European Standards (EN 13201-2) prefer to adopt the heuristic approach of considering different lighting classes with different requirements (luminance level and uniformity of the road surface) according to a number of influence parameters, the designer shall analysed in a risk analysis.

The main sticking points of STV approach in road lighting are in the difficulties in evaluate the correct luminance of the target surface and as a consequence its contrast and therefore the above mentioned metric.

The first point is important because the target luminance depends on the vertical illuminance due to the lighting installation but also on the light reflected by the road surface versus the target and on the contribution of the vehicle headlamps that is not negligible at the distance between 60 m and 100 m where the standards define the grid of points on the reference surface for luminance calculation.

2. Methods

As a consequence, the STV approach is not used for design of road lighting installations but last year the Italian normative body (UNI) introduced a technical specification (UNI/TS 11690:2017) where a simplified approach of the classical STV is proposed to resolve two aspects in the evaluation of a road installation design.

The standard evaluate a parameter called FVO (Fattore Visibilità Oggetti, i.e. Object Visibility Factor) of a lighting installations previously designed considering the Italian standard UNI 11248 and the European standards of the EN 13201 series. The obtained value can be compared to proposed benchmark values.

In Italy we follows the European approach of lighting classes. A reference lighting class is selected according to road classification. This lighting class has the highest performances. From this stating point, the designer gives a weight to different influence parameters and adding their weight he could obtain a lower performance lighting class (i.e. a higher number in the EN 13201-2 classification). Except for peculiar adaptive system, this change can be done only in discrete steps (e.g. from M2 to M3) and as a consequence the sum of the weight factors can reach at least an integer number. When this is not obtained, it could be interesting to have a new influence parameter, to verify if with this new one the integer value can be obtained or exceeded. If the FVO of the installation working in the

original lighting class is greater of the benchmark value for this class then the designer has a new possibility to justify the reduction to the lighting class with lower requirements. Of course only the luminance level and not the uniformity can be reduced and the new conditions shall produce an FVO of the installation greater of the benchmark value proposed for the new lighting class.

Several times customers has to select the right lighting installation design choosing between several proposals that equally satisfy standard requirements. The first and simple approach is to compare the installation cost, but also the maintenance costs influence the final decision.

The European standard EN 13201-5 introduced two energy performance indicators; they can be used to better evaluate the management costs. If after all this comparisons there is not a clear winner design, FVO can help: the installation with the greater FVO gives also better visibility conditions and has a greater probability to assure adequate safety conditions.

3. Results

This paper describes how the FVO has been obtain form the original STV model and compares the discrepancies between the two approaches, the peculiarities of the Italian standard and some of its application.

The standard is proposed for road lighting applications but it can be used in tunnel lighting too, an example is considered following the design rules in the Italian standard for tunnel (UNI 11095 considering the last draft of the new revision).

An approximate analysis of the influence of vehicle headlamps and road surface reflectance is proposed too.

4. Conclusions

The technical specification is actually in use in Italy and results and difficulties in its use be discussed next year in the technical working group of UNI.

ROADS MARKINGS VISIBILITY: DOES IT DEPEND ON THE APPARENT PERIMETER OR ON THE APPARENT SURFACE?

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Abstract

1. Introduction

Several models have been developed to predict the visibility distance of road markings, both in the US (DETECT/PCDETECT, CARVE/TARVIP) and in Europe (CIE 73 / COST 331).

The visibility level is the ratio of the luminance contrast between the road markings and the road surface, on one hand, and the contrast threshold on the other hand. To calculate the contrast threshold C_{th}, all these models refer to Blackwell's data or to Adrian's model. However, Blackwell and Adrian predict the contrast threshold of a uniform disk on a uniform background, while road markings are seen by the driver with a polygonal shape. Therefore, road marking visibility models use some assumptions allowing to convert a polygon into a disc of a given size.

Various hypotheses have been used, depending on the models, to estimate the disc radius of the equivalent target (in order to use psychophysical data of discs detection). Some compute the diameter of a disk which has the same apparent area as the road marking (CIE 73, COST 331), and some other compute the diameter of a disc with the same apparent perimeter as the road marking (DETECT). Finally, the CARVE model directly use the apparent width of the road marking as the diameter of the disc, and compensate for the overestimation of the resulting visibility with a calibration step.

These approaches speculate about how the shape of a target affects its visibility. Indeed, vision science literature reveals some influence of the target shape on visibility, in addition to the impact of the apparent size (Ricco's law).

The visibility of road markings cannot be directly estimated from laboratory data, and experimental data on the road has been collected for the tuning of all the above mentioned models. But some unverified assumptions are still present in these models, and especially when it comes to the computation of the equivalent disc which allows to use laboratory data. In this context, we have investigated the influence of the shape of targets with the same apparent size as horizontal road markings on contrast threshold, with a background luminance of 1 cd/m^2, which is consistent with the illumination level of urban streets at night. To that purpose, a psychophysical experiment was conducted in a laboratory.

2. Methods

A set of targets with the apparent size of the horizontal road markings was used. In total, contrast thresholds of six disks and six squares with apparent widths from 0.04° to 0.32° were collected. Eight participants between 20 and 29 years were involved in the experiment. A pre-test was carried out to select participants with similar contrast sensitivity.

The twelve targets were displayed on a HDR display device (Sim2, 47' full HD screen, 1920×1080). This device allows displaying small enough contrasts (from visible to undetectable contrasts). A uniform background luminance of 1 cd/m² was displayed, to be representative of an illuminated road. Participants were seated at 3 m from the screen.

For each target, a sequence of 110 stimuli was designed: 10 stimuli with different target luminance repeated 10 times, and 10 control stimuli (without any target). The order of the stimuli in each sequence was random. The sequences of 110 stimuli were displayed in a random order, too. Each stimulus was displayed for 0.2 seconds, and then the participant has 1.5 seconds to say if he detected it. A rest time of 1.3 second was added between two successive stimuli. An acoustic signal rang 0.3 seconds before the appearance of each stimulus.

3. Results

Disk and square with the same apparent surface produced nearly the same contrast thresholds (RMSE=0.07). Conversely, contrast thresholds of disks and squares with the same apparent perimeter, lower than 0.65°, were found different (RMSE[P<0.65°]=0.25, RMSE[P>0.65°]=0.05). In addition, the contrast thresholds predicted with Adrian's model were similar to those collected in this experiment, either with square (R^2=0.99, RMSE=0.08) or disks targets (R^2=0.99, RMSE=0.06).

4. Conclusions

The psychophysical experiment conducted in this work shows that Adrian's model developed for the visibility of disk targets on the road is also relevant to predict the contrast threshold of square targets, in the size and luminance ranges of road markings at night. Indeed, when viewed from a vehicle, in the visual range of visibility distance (above 30 m), road markings have an apparent shape similar to a square to the driver's eyes. Therefore, these findings confirms that computing the equivalent diameter of a disk which has the same apparent area as the road marking is a wise approach for road marking visibility models.

ROAD LIGHTING MEASUREMENTS THEORY VS PRACTICE

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Abstract

1. Motivation, specific objective

The basis for the design and evaluation of road lighting parameters is a set of European standards, generally called EN 13201 Road Lighting. In 2014, the Technical Committee 169 "Light and lighting" (CEN/TC169 "Light and lighting") of the European Commission for Standardization published the first part of the new version of the existing standard - Technical Report, containing guidelines and procedures for the selection of lighting requirements. At the end of 2015, the remaining parts of the updated version of the standard were published, including a new one – the fifth part concerning the energy efficiency assessment of road lighting installations.

The basic lighting requirements for roads designed primarily for motor traffic with high and medium speeds shall be based on criteria related to the level and uniformity of luminance of the road itself, the illumination of its immediate surroundings and an appropriate limitation of glare. In fact, the design of road lighting contributes to improving the safety of drivers and pedestrians involved in road traffic.

The current standards recommend that, in order to match the measured values with the calculated values, the location of the measurement points and the observer's position should correspond to the positions used in the calculations. It is recommended that these items also comply with the requirements of EN 13201-3. Application of such requirements leads to the following problems:

- A very large number of measuring points are created,
- Measurement of luminance distributions becomes a difficult task.

Field measurements of luminance uniformity are performed whenever the road lighting design objective select M lighting class. In Poland road lighting is installed on express roads and highways intersections and the roads in the close proximity of these. It follows from extensive experience of the team of Poznań University of Technology that it is practically impossible to perform a reliable measurement, especially of luminance distribution, and it is impossible to obtain an objective value of luminance uniformity especially when parts of the roads are not straight and even enough to perform the evaluation and often the measurement results do not meet the design requirements.

2. Methods

A number of measurement with a spot luminance meter as well as an Imaging Luminance Meter were made. Various lighting scenarios calculations of existing parts of the express ways and highways intersection regions were analyzed. The measurement results were compared with the calculations from preparation of light design plans for those parts of the roads. This work identifies obstacles and challenges connected with the luminance distribution verification on the roads which are not ideally straight and even.

3. Results

The results of the study indicate problems connected with the effective luminance uniformity evaluation performed with the use of luminance meters available on market. These problems become even more significant when measurements must be performed on the parts of the roads already commissioned. It shows from the available data analysis that the results from measurements made on existing (not ideal) parts of the roads are much different from the calculations prepared at the design stage. It is significant that the measurement results often indicate lower lighting class then the one taken into consideration at the design stage. Discrepancies appear when the luminance method is selected (M lighting classes) and it is impossible to perform measurements on flat parts of the road.

4. Conclusions

The team of the Lighting Engineering and Electroheat Division of the Poznań University of Technology has many years of experience in performing road luminance measurements using both spot luminance meters and Imaging Luminance Meters (ILM). The use of a ILM significantly simplifies the measurements and helps to obtain more reliable results allowing for unambiguous evaluation of the condition of the road lighting system.

In order to adequately asses the lighting condition in the specific locations is to have a common understanding of methods and results reporting. An important task for future will be to specify requirements for illuminated roads which are in the closed proximity to intersections and therefore are not straight and even. At least a specific guidelines should be developed to allow comprehensive interpretation of the standard in this regards.

Additional conclusion from the practical measurements experience is that the luminance measuring systems available on the market today are difficult to be used in the field as they are complicated in operation and not fully adapted to make luminance measurements on roads in accordance with the requirements of PN-EN 12301. The future system development should include a reliable power supply, markers for marking the measuring field, optics adapted to the width of the measuring field and an integrated module that allows one person to quickly and efficiently set up the measuring system in a given position, taking into account the requirements of EN 12301,

ROADWAY LIGHTING MAY COMPENSATE OLDER DRIVERS' REDUCED DARK ADAPTATION SPEED AND IMPROVE THEIR TARGET VISIBILITY

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Abstract

1. Motivation and objective

Most components in the human visual system deteriorate with ageing. Among such senescent changes in vision, older drivers' lower visual sensitivity in the dark and the slower dark adaptation the most seriously raise risks while driving at night. When older drivers look at a lit roadway surface and a dark roadway shoulder alternately, they have to alter their adaptation luminance levels frequently, and therefore experience substantial delays in adapting to brightness and darkness. Based on the above described fundamental findings, it is important to provide more appropriate roadway lighting for older drivers so that they can drive more safely at night.

To compare the ability of bright-dark adaptation between young and older people two experiments simulating simplified night time driving scenes on a computer display. They were (1) foveal vision experiment and (2) peripheral vision experiment. In the foveal vision experiment, the subjects recognized foveal target orientations while the adaptation luminance was changed in the foveal visual field. In the peripheral vision experiment, they detected off-axis targets while the adaptation luminance was changed in the peripheral visual field. Based on the results of the two experiments, this study discussed the importance of roadway lighting for older drivers.

2. Methods

Both experiments employed a single experimental setup. The setup consisted of a personal computer, a display, a keyboard, a mouse and a chinrest. In both experiments, nine young subjects (22 to 27 years old) and seventeen older subjects (61 to 69 years old) participated.

The first experiment evaluated the adaptation ability of the foveal vision for young and older subjects. The simulated driving scene was divided in two, i.e., a low luminance (0.7 cd/m2) part and a higher luminance (1.2 cd/m2) part. In the centre of each part, a target was presented. This experimental scene simulated a typical eye tracking task while driving. While fixating on each of the two targets alternately, the subjects adapted to the brightness of the background. The target was a Landolt ring with a gap width of 0.2 degrees. The luminance of the target was changed in four conditions.

In the first experiment, a subject was seated before the display at a distance of 65 cm. As soon as the subject recognized the orientations of the Landolt rings, the subject responded to the target presentations by pressing corresponding keys. After the subject detected a target presented on one side and pressed a key, the target disappeared, and the other target was presented on the other side. This procedure was repeated thirty times. The computer recorded the subject's responded orientations and response times between when the targets were presented and when the subject pressed correct keys.

The second experiment was conducted to investigate the adaptation ability of the peripheral vision for young and older subjects. On the display, presented was another driving scene divided into three, i.e., the central fixation field with a luminance of 1.2 cd/m2 and two darker peripheral visual fields. There was a fixation point in the centre of the fixation visual field. A disk target with various luminance levels was presented in the centre of the left or the right peripheral visual field. The left and right targets were presented in a random order. Every time when a target was presented, the luminance of the peripheral visual field was altered between 0.7 cd/m2 and 0.2 cd/m2. The subject was asked to respond to the target presentation as soon as the subject detected the peripheral targets. The computer recorded the responses and reaction times of the subject.

3. Results

The correct response rates were averaged in each of the young and older groups for each of the foveal vision experiment and the peripheral vision experiment. From the results of the foveal vision experiment, it was found that the correct recognition rate increased as the luminance of the Landolt ring target increased for both young and older subject groups ($p<0.01$). In addition, the results suggested that for the same target luminances young subjects recognized more targets than older subjects for both the dark and bright adaptations ($p<0.05$).

From the peripheral vision experiment, it was found that the off-axis target detection rate increased as the luminance of the Landolt ring target increased for both young and older subject groups ($p<0.01$). The results also suggested that young subjects detected more targets than older subjects only for dark adaptation ($p<0.05$). However, there was not a significant difference between young and older subjects for the bright adaptation. This implies that the deterioration of the ability of bright adaptation with ageing is smaller than that of dark adaptation.

The subjects' adaptation speeds were measured by using the obtained reaction times. The results of the reaction times showed similar tendencies to the results of the response rates. It was found that older subjects needed longer adaptation times than the young subjects in both the foveal and peripheral visual fields.

4. Conclusions

The above described results of the two experiments confirmed older peoples' lower visual sensitivity in the dark and the slower dark adaptation. This implies that appropriately illuminating peripheral areas adjacent to roadways may compensate older drivers' slower dark adaptation speed and improve their target visibility.

The slopes of the regression curves for the older subjects were less steep than those for the young subjects. This implies that the older subjects had more individual deviations than the young subjects. Therefore, it is necessary to correct data from larger number of subjects, but carefully analyse the data individually. It is also important to evaluate older subjects in their 70s and 80s who may have larger individual deviations.

AN EEG BASED APPROACH FOR IDENTIFYING PROCESSING DIFFERENCE OF LIGHT SPECTRUM IN ROAD LIGHTING TOWARDS OBJECT DETECTION

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Abstract

1. Motivation, specific objective

With the development of latest technologies in lighting engineering, a good amount of effort have been made to address the challenge of making an elegant road lighting solution based on different parameters like illuminance, luminance, uniformity, threshold increment etc. A technically sound lighting solution designed on the basis of these parameters may evoke differential perceptual experiences among pedestrians and drivers. A wide range of perceptual experiences have been reported by the road user under different road lighting conditions. Behavioural results of different perceptual experiments, done in different road lighting conditions also fail to give a clear picture of this situation. Detection of objects under different lighting conditions is affected majorly by subjectivity in perceptual experience. Further, majority of studies account for rod and cone activation and how it affects the spectral luminous efficiency V(λ) of the human eye . But how the lighting condition triggers higher level brain processes and cortical circuitry is still unknown. Hence, human cognition under lighting conditions present a complex yet scarcely investigated scenario. Added to this is the colour appearance of streetlights such as metal halide (MH) and high pressure sodium vapour (HPSV) lamps. As a result even simple object detection becomes highly complex. In the present study, we use EEG to compare the object detection ability of human participants under MH and HPSV. The results suggest distinct brain activations for MH and HPSV.

The objective of the study is to test and evaluate the processing differences in object detection under MH and HPSV using electroencephalography study.

2. Methods

Substantial portion of the literature in road lighting experiments investigated the preference bias in object detection under metal halide (MH) and high pressure sodium vapour (HPSV) lamps. On the basis of these perceptual experiments it is well evident that preferences in both the conditions exists in different experimental set-ups, and this is probably because of a difference in that, how human brains perceive these lighting conditions from the context of object detection. Thus the situation demands more temporal detailing, i.e. a time course activity study of on-going brain processes under MH and HPSV. Dynamic changes occur during object detection under both types of light sources with two different spectral compositions. Hence, this event related potential based study may reveal the dynamic changes associate with a series of events while detecting an object with respect to its background. It may serve as a more potent approach to analyze the ability of an observer to detect an object under two different light sources.

This paper presents a subject detection task under two different lighting conditions i.e., MH and HPSV lamps. During the task, ongoing electrical potentials of the participants were measured to evaluate the processing differences under MH and HPSV. Hence, the entire study has been divided in two segments behavioural study and EEG based study

3. Results

From our experiment it was found that for the MH matched condition the mean response time of the all participant is 1517 ms which is less than the mean response time (1553 ms) for the HPSV matched condition.

It was also found that the accuracy of right object detection is more under MH matched condition than HPSV matched condition. The total number of inaccurate responses for MH matched condition is 21 and for HPSV is 26. It can also be found that 55 % of the total wrong responses are occurred under

HPSV and one-third 45 % under MH. So, it can be said that participant are more accurate to recognize an object under MH than HPSV in this study.

Grand averaged Event Related data shows difference in early activity in the time interval 150 ms–200 ms. For MH there is a larger negative contour at 150 ms–200 ms ($p < 0.05$) over right occipital and parieto-occipital electrodes. The area classically houses the primary and secondary visual cortex of the right hemisphere of the cortex. For HPSV, the occipital and occipito-parietal electrodes activate bilaterally.

4. Conclusions

In the present study, behavioural response and perceptual processing of the participants under two light sources, i.e. HPSV and (MH), have been observed. In the present study, no significant difference was found in the behavioural response under two light sources. However, this study reveals a significant difference in brain processes during object detection under MH and HPSV. These differences are evident from the EEG results. Bilateral activity in the occipital and occipito-parietal electrodes is observed in the time interval 150 ms–200 ms ($p < 0.05$) under HPSV. Under MH, a large negative peak appears at 150 ms–200 ms ($p < 0.05$) only over right occipital and parieto-occipital electrodes. The current result indicates that perceptual processes differ under different lighting sources.

This experiment can also be done for the LED based road lighting systems to find out how these spectral compositions affect perceptual processes. The technical parameters like illuminance, luminance, visibility level, contrast, glare etc. can also be verified for perceptual processes.

AN IMAGING TOOL TO MEASURE GLARE DYNAMICALLY

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Abstract

Road lighting audits imply to know luminances on the pavement and can be achieved by calibrated imaging systems. Glare evaluation requires to have access to sources luminances without sensor saturation and classical imaging systems are then inefficient. Capturing low luminances and high luminances in the same image is known as High Dynamic Range (HDR) imagery and the technique used here is based on four cameras, each dedicated to one luminance range. Then an image processing algorithm constructs the final 20-bit HDR image. From HDR images, visual adaption and threshold increment models are computed in order to measure glare dynamically along a tramway route.

1. Motivation

Evaluating road lighting performances is possible nowadays by mean of digital cameras. The first need is to acquire luminances on the roadway to check normative standards. A second step, reachable with High Dynamic Range (HDR) capabilities, is to measure luminances inside sources (previously always saturated). It opens the way to many calculations made until now only statically and punctually with a luminance meter. With an HDR Imaging Luminance Measuring Device (ILMD) able to measure from 0,1 to 10^5 cd/m² and the methodology described hereafter, we developed a tool to quantify the disability glare along a route. The process consists of recording images as close as possible to human eye sensitivity and computing visual adaption and disability glare models.

2. Methods

Several techniques and architectures exist for extending image sensor dynamic range. The chosen technique is derived from multiple capture technique: several images are taken with different exposure times: short integration time captures high lighted regions and long integration time captures low lighted regions. The imaging system is based on four cameras, each dedicated to one luminance range. The signal over noise ratio is not affected and maintained over extended dynamic range. As the raw signal is used, the camera response is linear and conventional photometric and colorimetric calibrations can be performed. The photometric process leads to set the exposure times in the four cameras as well as objective F-number to obtain a theoretical global dynamic range of 20 Exposure Value (EV). A total luminance range between 0,1 cd/m² and 10^5 cd/m² is obtained. Precautions are also taken to correct non-uniformity due to optics and sensors recording flat-field and dark images.

The synchronization issue is solved by using four hardware triggered cameras. The time-lag has been measured inferior to 1 ms. The system is then embedded in a vehicle to acquire images dynamically. This configuration based on four cameras leads to four images with different points of view and classical image registration algorithms cannot be applied. The setup can be assimilated to a multiple stereoscopic system and a rigorous geometric calibration will allow to facilitate the HDR reconstruction. This specific process permits to retrieve a point source from one camera in the three others within a field of view of 0,5°. This is a key point to construct HDR images. Combination of all images into HDR image is then required using a HDR construction algorithm.

3. Results

The developed algorithm's purpose is to replace saturated zones where the measurement has failed by zones acquired in other images where the measurement is valid. A registration is then computed zone by zone and pixels replaced in the main image to obtain a complete well exposed image known as HDR image. HDR (or classical) images permit to measure and calculate standard parameters on the pavement: average luminance, longitudinal and overall uniformities. HDR (but not classical) images give access to sources luminances and high lighted regions without saturation. Therefore disability glare model as Threshold Increment (TI) can be applied to evaluate glare dynamically along a route. But this model is very expensive regarding processor calculation time and we propose an alternative model based on vision mechanism. The philosophy is to adjust sensor response to the incoming light like our eyes do in real life. For each scene pixel, the model computes retina-like response signals for cone and rod luminance. As an output, the visual adaption model gives the adaption luminance, the saturated and underexposed zones in relation with cone and rod response. We finally compare the two models along a tramway line and discuss about detected glare zones.

EFFECTS OF EYE DISEASES / OPERATIONS AND EYEGLASS PROPERTIES ON VISIBILITY ON ROADWAY LIGHTING

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Abstract

1. Motivation, specific objective

Luminaire features changes rapidly in the last decades. These changes cause changes also in roadway lighting visibility. On the other hand medical science and medical nanotechnology changed also rapidly in the last decades. These caused new vision modalities in many patients, who are healthy enough to be mobile as drivers or pedestrians. In developed countries more than the half of the population (up to 60-75 %) wear glasses or contact lenses. For driving licences is it mandatory to wear glasses to achieve a certain level of visual acuity. So even the occasional glasses user people put on their glasses when driving. The visibility on roadway lighting for drivers or pedestrians depend among other factors on the glass properties of their glasses. In the last decades these properties changed rapidly. So different the effects of these glass properties of glasses on roadway lighting luminaires should be taken into account. The combination of technical and scientific and practical changes in illumination and ophthalmology make new ways of thinking necessary.

2. Methods

The perception of new lighting luminaires and the light properties on different surfaces are compared with the patients' visual perception who has ocular diseases and/or had ocular surgery. The eye glasses have properties which change the illumination in the environment in different ways for different purposes. The effects which are beneficial in daylight, may be disadvantageous in artificial lighting especially in roadway lighting. The different properties of luminaries for roadway lighting are compared with the properties of glasses. The material of eye glasses, colour of glasses, coatings of glasses and layers of glasses may have enhancing or reducing effects for roadway lighting.

3. Results

There are many eye diseases, which change the visual perception. Some of them have been untreatable in the past. Today there are new therapies or surgeries for some of them. So there are some people on the road who have ocular diseases or therapies and some changes in the visual perception due to the progress in medicine which can change visual perception. The implantation of different intraocular implants (lenses and telescopes) change the visual perception optically. Roadway lighting perception may be also changed in these patients. There are many young people in society, who had laser refractive surgery. For some of them the visibility of the roadway lighting may have changed due to the new optical configuration in the eye. The material of glasses (Crown glass, organic, polycarbonate, Trivex) may change the dispersion, producing haloes depending on the spectra of luminaires. So the visibility changes through the interaction of roadway luminaires and headlamps of cars with eye glass material. Colour of eye glasses have a filter effect for the opponent colours in the spectra of luminaires. Especially for luminaires with diverging spectra from daylight, the effects may be more pronounced. There are some coatings on eye glasses. Coating which are important the illuminant light properties are antireflective coating and mirror coating. Antireflective coatings on eye glasses reduce the reflection of light on eye glasses for targeted wavelengths. So there are less reflection the glasses. Which is good for the driver or pedestrian for not having glare due to reflection on glasses. The mirror coating cuts 60 % of light which goes through the glass. It may be dangerous to use mirror coating at dark even with roadway illumination because due the diminished illumination, the visual functions may be not enough for driving. An important layer of eye glasses for the effect of light sources are polarising filters. As the only eye glasses filter which can change the light properties on the fixated object, polarising filter changes the reflection and (potential) glare effect on the objects. The viewer can see the colour of the object better due to lessened reflection on the surface of the object. On the other hand the illumination is diminished due to extinction of light in some angles due to the effect and extent of the polarising filter. All these effects of eye glasses properties may be more

pronounced in roadway illumination (from which the properties are different from daylight), because the eye glasses are mostly designed for daylight.

4. Conclusions

There are many people on the road, who see differently due their eye diseases. On the other hand due to new techniques in ocular therapy and ocular surgery many patients can see better than some decades ago. There is also changes in roadway lighting luminaires and lighting designs. It can be advocated, to bring the new knowledge and practice level in ocular medicine and illumination, to have better performance with new techniques for normal people and the treated/operated (and non-treated) patients. On the other hand material of eye glasses, colour of glasses, coatings of glasses and layers of glasses which are worn by the drivers or pedestrians may have enhancing or reducing effects for roadway lighting. The knowledge of these effects may be helpful in designing new concepts of roadway lighting. The effects of the eye glasses may also be optimised for roadway lighting.

A COMPARISON OF THE CIE MESOPIC PHOTOMETRY WITH A NEW BRIGHTNESS MODEL

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Abstract

1. Motivation

To describe mesopic visibility, we need a mesopic contrast metric operating at a certain adaptation level (“working point”) around the detection threshold. Our hypothesis is that this working point can be characterized by a mesopic brightness model.

2. Methods

To test this hypothesis, first our new (2018) brightness model will be presented based on our new visual brightness experiments in the mesopic range (at 0.3 cd/m2 and 1.5 cd/m2) with 6 and 11 channel LED light engines.

Then, this new brightness model will be compared with the Berman et al. and Fotios et al. brightness models as well as the CIE mesopic visual performance model (CIE 191:2010) based on a computation for typical exterior LED light source spectra.

3. Results

It will be pointed out computationally that the higher metric brightness value of a mesopic scene implies a smaller value for the mesopic threshold contrast necessary for the safe detection of hazardous objects.

VISIBILITY – VISUAL PERFORMANCE BEYOND THE EYE OF THE BEHOLDER

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Abstract

Public lighting aims to enable people to see the relevant objects in their environment. It seems logical to use the visibility of such objects as a quality criterion for public lighting. Although several methods have been proposed to quantify visibility, these metrics have not found widespread practical application.

For safe traffic participation, visual information is crucial, but next to good vision, it also depends on a correct and timely cognitive analysis and on choosing and performing the appropriate motor actions. On all these aspects, drivers will generally perform worse than expected from laboratory experiments. Apart from the workload and distractions associated with driving in the real world, also ageing of our visual-motor system will reduce our performance. Although up to 80 % of current traffic accidents are categorized as ‘looked, but failed to see’, current analysis of lighting needs is still based on ideal observers in controlled circumstances, with yellowing of the eye lens as the only ageing effect, if any.

Thanks to digital technology the visibility of realistic, irregular objects can now be quantified using a model based on human spatial vision and the necessary input can now be measured using digital imaging luminance cameras. Combining this with the latest insights in how our visual-motor system functions and ages, and modern experimental techniques, we should be able to give a better indication of the lighting needs of real people in real circumstances.

Recent advances and possible directions will be presented to provoke a discussion on the way forward to guarantee a higher level of safety and comfort for all drivers.

COST-BENEFIT ANALYSIS OF USING VISIBILITY CONCEPTS

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Abstract

The frequency and severity of road collisions are reduced if drivers are able to detect and recognize potential hazards in sufficient time to take evasive action such as braking and steering. An improvement in detection time measurable in hundreds of milliseconds could substantially increase the probability that a crash can be avoided.

After dark, visual functions such as reaction time are significantly reduced, and road lighting is installed as a countermeasure to this visual impairment. Road lighting is of particular importance for revealing hazards beyond the reach of vehicle headlights such as pedestrians emerging from the side. The British Government recognise the need for significant reductions in road traffic collisions, particularly those involving vulnerable road users such as pedestrians, and committed to enhancing protection of these people in the 2015 British Road Safety Statement.

This project will investigate the way in which lighting can be used to enhance safety on main roads. Specifically, we seek lighting that increases the chance of drivers seeing a hazard and reduces the time taken to see the hazard. These hazards include other vehicles, stationary objects and pedestrians.

There are two problems with the current situation. First, while British and European standards provide guidance on road lighting, the empirical basis of the recommended lighting is not clear. Therefore, we do not know whether they recommend optimal conditions. Second, we suspect there is a better way for enhancing the detection of pedestrians when they are otherwise unexpected, which is frequently the case for pedestrians on main roads. This is that pedestrians should use a pulsing or flashing LED band, worn on the wrist or ankle to take advantage of bio-motion. An LED band could provide a low-cost counter-measure to reduce the risk of accident.

To investigate these proposals we will first carry out experiments to find out how the detection of hazards including pedestrians is affected by changes in lighting, using variations in the intensity and spectrum (colour) of lighting. Whilst drivers should be continuously scanning for potential hazards, there are many distractions - listening to music, speaking to passengers and looking at maps or digital navigation devices. These distractions reduce our ability to detect hazards. We will therefore also investigate how hazard detection is affected by distraction and whether optimal lighting can mitigate the distraction decrement. This research is of particular benefit to elderly drivers; the elderly tend to have poorer vision and, overall, they perform worse than younger people when driving with distractions.

From these data we will identify the changes in lighting conditions likely to improve safety. These recommendations will be validated by manipulating lighting conditions within a high fidelity driving simulator. The simulator places the test participant in a more realistic setting while still maintaining control on road situation and ensuring participant safety. To facilitate implementation of results we will work to ensure the guidance and standards documents used by lighting designers are revised to include the proposed criteria.