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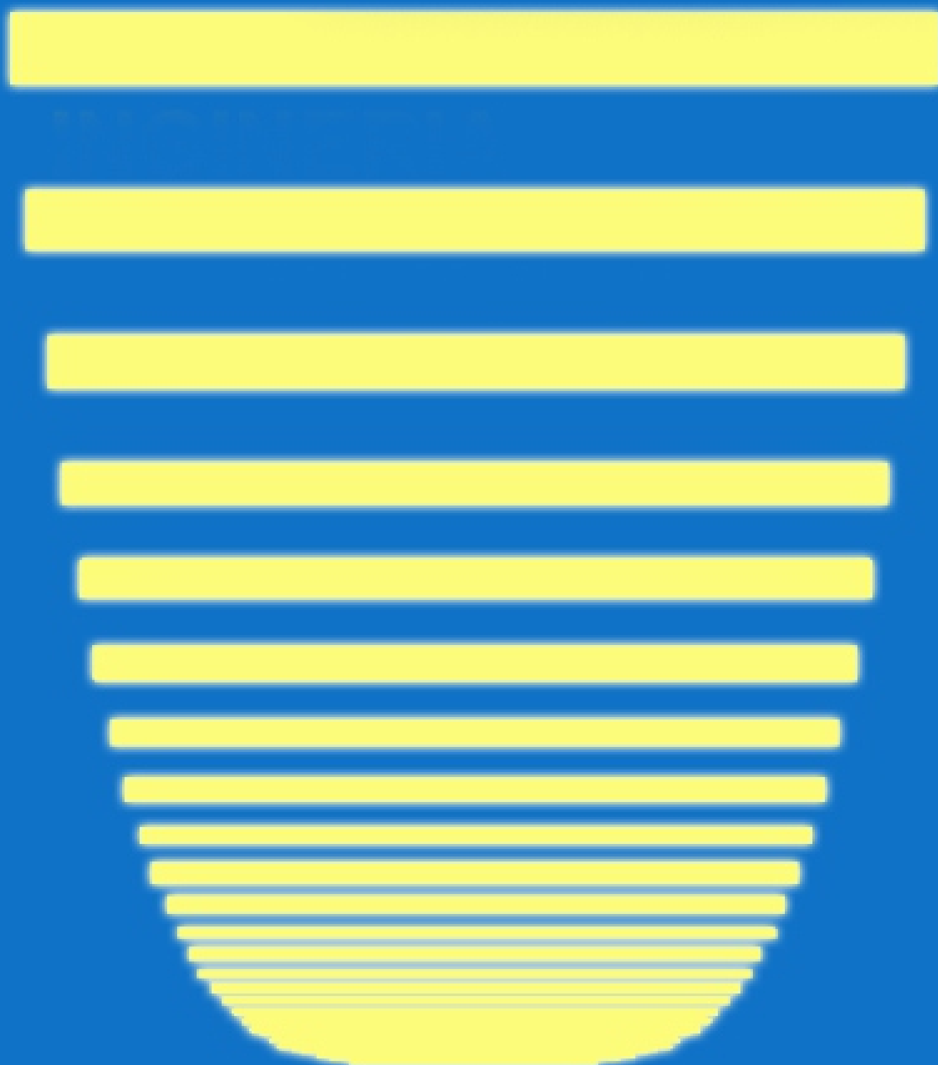

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INGINERIA ILUMINATULUI – Journal of Lighting Engineering - is a publishing media for valuable original scientific papers in the field of lighting engineering. The papers proposed for publication are considered based on their originality, meaningfulness and area of interest. In order to be accepted, the papers have to be remarkable in their field. The papers are evaluated by two independent reviewers. The contributions have to conform to the generally accepted practices for writing scientific papers, with respect to paper organization and style of writing.

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INGINERIA ILUMINATULUI - Journal of Lighting Engineering - has a scientific presentation and content, targeted to the continuing education in the lighting field. The objectives of the journal consist of the presentation of results of lighting research activity, dissemination of lighting knowledge, and education of interested people working in public administration, constructions, designers, dealers, engineers, students and others.

Its content is organised in six parts: Editorial, Papers, Theses and Dissertations, Conferences and Symposiums, Information, Anniversary.

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LIGHTING EDITORIAL 4.0

Dorin BEU

The number represents the qualification code of Lighting Specialist in the Romanian Register of Regulated Qualifications, in the major group 2142 – Civil Engineering.

Let's start with the beginning: in 2012 the new Board of Administration of Romanian National Committee of CIE - CNRI (Mihai Husch, Marilena Măierean, Dan Vătăjelu and myself) start a discussion about who can are the lighting specialists. The problem is all over the world (people who work have different universities background, few have master studies and many claim they are lighting designer, experts etc.). In one hand no one want to limit the access to a job in lighting and in the other hand we want that lighting specialist become a regulated qualifications. This issue may raise discussion about over regulations, but after all we have standards and codes that need to be followed by everyone in this sector. In the case of peoples who have worked many years in lighting, with a lot of practice in the area, we need to confirm their competences. This issue is delicate, as a person with twenty years of experience will reluctant to the idea of an exam, so the solution we have found is a portfolio of previous works and a discussion with professionals that can certify the level of knowledge (a sort of peer-review).

The solution that we think is an answer is to regulate the qualification of lighting specialist. For this CNRI have hired a human resources company who have prepared all the paper and who through questionnaires and studies have established all the competences needed for this qualifications. The time we have spent in preparing the amount of birocratic papers (like job description) helped us to clarify many aspects and a better understanding of our profession.

The next step is to organize qualification courses which will start in September in Bucharest and then in Cluj-Napoca.

In the same idea, I must congratulate Dimitrios Zevgolis and Frangiskos Topalis for organizing the LiDe summer course (details at **http://ip2013.eap.gr** and in our journal) in Athens. Bringing 32 students and 18 lecturers from Greece, Turkey, France, Germany, Belgium, Slovenia and Romania it's not an easy task but it will promote lighting among the new generation of lighting specialist. Next summer course will be held in Porto. Being one of the lecturers, I may be subjective, but I am always happy when lighting is promoted from different perspectives and this will

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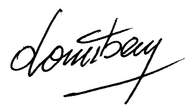
influence students and most of them will keep going in this direction. I wish I have participated to such a course at the end of my studies.

Two words about the two most important conferences of this year in Europe: one was 100 years of CIE held in April in Paris and second will be in September in Krakow. If for the first one I can regret that some of the important lighting professors were not there, I can recognize that it was the first green one. For the second one, there were not enough at the beginning and for both of them I can say that there is a problem, that they don't have an ISI proceeding, which is a pity. I know that CIE is working in this direction and I think that this is vital for our future.

At the beginning of this year, between 30 January and 28 April at the Hayward Gallery, London was the biggest exhibition with lighting artist – Light Show. Unfortunately I could not visit it, but a very dear friend of mine sends me the exhibition book. It includes all lighting artists, starting with Dan Flavin, passing by James Turrel and ending with Olafur Eliasson. All of the worked with the immaterial material which is light and it is fascinating to see how they are shaping light and play with our perception. Sometimes, for me as an engineer, it is hard to explain to my students what is the difference between some bare battens leaned on a wall by a contractor and the same thing done by Dan Flavin becomes art. In our journal authors try to explain the scientific part, but when it comes to art you don't have to explain everything. This is the beauty of lighting: it is both science and art.



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USING BLUE WAVELENGTH LIGHT TO MODIFY COGNITIVE FUNCTIONING. CAN FULL SPECTRUM FLUORESCENT LIGHTING IMPROVE WORK RELATED CONCENTRATION IN THE CLASSROOM?

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The University of Huddersfield, U.K.

Abstract: *Some researchers make the claim that full spectrum fluorescent lighting can positively affect cognitive performance and well-being and yet the impact which full spectrum fluorescent lighting has upon cognitive functioning remains in question. In spite of extensive laboratory research into the effects of lighting on neurological processes, little scientific evidence proving that cognitive functioning can be altered by working under full spectrum lighting is lacking. This study sets out to determine whether levels of concentration can be improved through the use of full spectrum fluorescent lighting used in the classroom on a randomly selected group of thirty-eight Further Education students where 19.4% of the student population have been diagnosed as having ADHT, Asperger's and Dyslexia. Lighting has been linked to learning, furthermore lighting which supports concentration may be very useful in promoting classroom behaviour and learning. Moreover excluding students from mainstream schools and placing them into pupil referral units cost the British taxpayer in 2010/2011 in the region of £81 million compared to the cost of £34 million if those students had remained in full-time education. Using full spectrum fluorescent lighting may help to achieve better classroom behaviour and a viable way in which to reduce the student exclusion rate. Rather than using a laboratory type environment as many previous studies have, this study uses a work based environment in which to collect data.*

Keywords: impacted, students.

1. Introduction

Having worked in the electrical industry and the education service during the past thirty years, my attention was drawn to the effect which fluorescent strip lighting had in the workplace and especially the impact on the classroom environment with regard to flicker, glare and brightness which this type of lighting produces.

There appears to be widespread concern within the teaching profession and Ofsted that some learner groups for varying reasons are disruptive in class, additionally the 2013 Ofsted framework for school inspection indicates that ways to improve low level background disruption during lessons should be considered. Furthermore minority groups requiring different forms of learner support are often those at risk of school exclusion sometimes through an inability to focus on task or through behaviours associated with autistic spectrum disorders (ASD's) or attention deficit hyperactivity disorder (ADHD). Statistics reveal that within this organisation students diagnosed as having dyslexia, dyscalculia, autism or some other learning difficulty comprise 19.4% of the student population in addition to others requiring learner support. According to the National statistics from the Department of Education (DfE; 2011) 5,080 permanent exclusions from state funded schools occurred in 2010/11, the cost to the taxpayer being in excess of £81 million compared to £34 million if those students had remained in full-time education.

Attempting to redress current knowledge regarding the impact of lighting upon cognitive functioning and behaviour in the classroom this study suggests that improvements to classroom lighting may positively influence the teaching and learning environment. Although the spectral qualities provided by full spectrum lighting (F.S.F.L.) have been reported as being beneficial for the health and development in children, current research in this field is still in its infancy (Boyce, 2003).

Recent research (Vanderwalle et al, 2009) indicates that the physical characteristics of ambient light are influential modulators of non-visual function such as; improvements in performance, heightened levels of alertness and noticeable improvements in various cognitive tasks. Moreover, there appears to be a shortage of information about the effects of lighting in the classroom researched outside the laboratory setting using large sample sizes. Therefore this study attempts to partially address these issues by using a sizeable sample size and by conducting the research in an active indoor classroom. In addition to conducting this research within the confines of an active classroom, a series of non-verbal reasoning tests given to students to determine levels of student concentration working under cool white fluorescent (CWFL) strip lights will be compared to the same activity working under FSFL.

Using Kerlinger's hypothesis (1970), "if X then O", this study suggests that using full spectrum fluorescent lighting (X) may impact concentration (O) of students working in the classroom. Furthermore this study proposes to use the following research question: Do students working under full spectrum fluorescent lighting concentrate more than when working under cool white fluorescent lighting?

2. Methodology

2.1 Design

This study used a multivariate analysis to illustrate variance. Spectra (dynamic versus static) represents the independent (x axis) variable and a dependent (y axis) variable; concentration, were used in this study. According to Campbell and Stanley (1963) a True Experimental design described by Kerlinger (1970) as a 'good' design was originally chosen by this study as an appropriate model to follow. Further investigation revealed that participants can become sensitised to pre-test conditions and this in itself was seen as a potential threat to validity, moreover Anastasi (1958) found that there was nearly always an increase in test scores between test one and test two by approximately three to five points on the Intelligence Quotient Scale. Furthermore any sensitising suggested by Anastasi (1958) may have resulted in a weakening of the research question as any difference between O_1 and O_2 scores may have been attributable to either X or the "carry-over" effect of sensitising. To overcome this particular issue this study considered using counterbalancing as a means of reducing sensitisation to pre-test conditions by spacing pre-test and test twenty-one days apart and by applying the following formula to the True Experimental Model, $(O_2\text{-}RO_1)\text{-}(O_4\text{-}RO_3)$ (Campbell and Stanley, 1963).

The Solomon Variant.

Experimental group has pre-test and treatment, whilst control group one has pre-test and no treatment. Control group two misses out pre-test but treatment is applied.

Experimental Group.	**RO_1**	**X**	**O_2**
Control Group 1.	**RO_3**		**O_4**
Control Group 2.		**X**	**O_5**

Figure 1

Further research was conducted to locate an alternative design based on the True Experimental Model recommended as an appropriate design for use in educational research by Campbell and Stanley (1963) and which had more flexibility in its design. Solomon (2001) found that sensitisation could be isolated by adding two further groups to the Campbell and Stanley (1963) design; one that does not undertake the pre-test and the other one missing out the experimental treatment. In common with the Campbell and Stanley True Experimental Model, the Solomon Variant experimental group could be affected by treatment or pre-test sensitisation and control group one affected by pre-test only. However by using a second control group without pre-test any effect in O_5 scores would be attributed to the treatment 'X' being applied. Amalgamating both educational and scientific research this study considered the Solomon Variant more appropriate than using the Campbell and

Stanley True Experimental Model which according to Cohen and Manion (2011) is commonly used for educational research. This study therefore proposed to use the Solomon Variant (figure 1) and to administer the test twenty-one days after the pre-test. A random sample representing 2.3% (38 participants) from the total student population was recruited. The sample size was considered manageable within the time constraints of this study although a much larger sample size would have been more representative of the student population.

2.2 Participants

The study followed The British Educational Research Association (BERA; 2012) and Code of Ethics for Social Work and Social Care Research (2012) protocols. The involvement of participants was purely on a voluntary basis. This study did not take into account personal circumstances, ethnicity, academic abilities, or health of any participant. Participants were not informed that different light sources would be used during the study as expectancy effects may have influenced the final results. During the culmination of the final experiment the precise aim of the study was announced to all those who volunteered to take part.

All participants provided written consent to participate in the study prior to any experimental research taking place. Appropriate authority from the ethical committee at the college was obtained prior to the commencement of data collection and this study considered that simple random sampling methods would be used to recruit participants.

2.3 The Instrument

Item Response Theory (IRT) and Classical Test Theory (CTT) were researched prior to writing the test for use in this study (Cohen et al, 2011) and were used to guide the pre-test and test papers with regard to: The purpose, achievement, objectives, content, construction, format, reliability and validity.

The test used in this study was piloted and verbal feedback given to indicate; clarity of the layout, the suitability for use with Further Education students, the level of language, the complexity of the test and the time taken to complete the test.

This study concluded that one of the most appropriate methods of achieving this would be to use a non-verbal reasoning test requiring participants to focus their attention on simple problem solving within a set time limit. (McClelland, 1973; Arthur, 1994 Rips,1994; Johnson-Laird,1997; Goel and Dolan, 2003). The test used in this study, presumed basic numerical and verbal ability, and was a test requiring participants to think broadly and visualise emerging patterns from a series of graphical images (DeGroot, 1965; Ennis,1981; Hitchcock 1983; Arthur, 1994).

2.4 Independent variable for Control

The existing lighting comprised of six 1.5 m fluorescent lights directly mounted onto the ceiling tiles, each fitting holding two 1.5 m 58 watt tri-phosphor fluorescent tubes. Each light fitting had an integral lightweight aluminium baffle masking the lighting tubes and provided some reflectance. Each fluorescent tube was a

T8 type, operating at 230 volts nominal voltage, 50 Hz and having a C.C.T. of 4000 Kelvin (K). The lamp type was commonly referred to as having a cool white colour. The illuminance at desk top height was in a range of 500-700 lux. Light levels were measured using an Ethos 5700 lux meter.

2.5 Independent variable for Experimental condition

Existing fluorescent tubes used during the control were removed and Edison EDF58/865 full spectrum tubes retro fitted. The retro fitted lamps were of the T8 type, operating at 230 volts nominal voltage, 50 Hz and with a Colour Correction Temperature of 6500 Kelvin (K). The illuminance at desk top height was in the range of 500-700 lux and light levels were measured using an Ethos 5700 lux meter.

2.6 The Experiment

The experiment was conducted in a small classroom with windows leading into a broad and well illuminated corridor; dark vertical blinds obscured most of the windows with at least 98 % of the total window surface totally obscured. The experiment was conducted with all window blinds closed to reduce any effect of natural daylight and to control extraneous factors such as: external noise, equal distribution of experimental illumination and seasonal levels of daylight. The classroom used for the experiment was 4.5 m x 6.08 m and 3 m high, the walls were fabricated from standard 404 mm x 202 mm concrete building blocks painted white. The environment of this field experiment for both Control and Experimental Groups was kept identical throughout the experiment in terms of classroom furniture, time of day and seating positions.

2.7 Control Group one

A randomly selected group of eight students whose ethnicity and gender was representative of the entire first year student population were used as a control group. The control group were asked to complete a non-verbal test under full cool white fluorescent lighting (C.W.F.L.) and twenty one days later the same test was repeated under the previous lighting conditions. According to the Solomon Variant (2001), control group one test results may be affected by pre-test sensitisation only as no treatment was applied.

2.8 Control Group two

Selected and matched in the same way to control group one, this control group of eight participants would undertake the test with treatment X being applied and missing out the pre-test. Control group two would spend thirty-five minutes under the full spectrum lighting (F.S.F.L.) prior to the test being administered as research has suggested that any non-visual effect of F.S.F.L. usually occur within one hour from time of exposure to that lighting source (Gifford and Ng, 1982). According to the Solomon Variant (2001) pre-test sensitisation would not occur and any effect on test scores attributable to the treatment applied.

2.9 Experimental Group

The Experimental group undertook the pre-test and twenty one days later the test with treatment applied. According to Campbell and Stanley (1963) and Solomon (2001) the experimental group may be subjected to any pre-test sensitisation according to Anastasi (1958) and also to the effect of the treatment applied.

3. Data collection and analysis

Data was collected at three week intervals between pre-test and test, furthermore pre-test and test were exactly the same as each other. Data obtained from the non-verbal reasoning test were subjected to quantitative analysis since this was one way of correlating results from this study with the results of research undertaken by Mills et al (2007). Questionnaires were completed by participants who undertook the test with the intervention X applied and the nominal data collected was subjected to qualitative analysis.

3.1 Data analysis: Experimental Group Results

The Solomon Variant of the True Experimental Design by Campbell and Stanley (1963) was used throughout this study. Twenty-two participants took part in the experimental group. Simple statistical analysis was used to compare results for each of the groups found in the Solomon Variant. Changes in RO_1 and O_2 scores were compared using mean averages taken from the percentage increase from pre-test to test conditions. Although some negative values were obtained in the O_2 test results these were included in the mean average calculations used to determine percentage increases from RO_1 to O_2. Even though the negative results had the effect of lowering the percentage increase from pre-test to test conditions this study deemed it necessary to portray a full and accurate account of all data obtained and further investigation to determine the reasons for negative results may prove to be useful. The mean score (ā) for RO_1 was calculated to be 5.818. The intervention X was applied three weeks later and the test given in the same classroom. The mean average for O_2 was calculated to be 7.955.

RO_1 ā 5.818 —— **X** ——> **O_2** ā 7.955

Three week interval between RO_1 and O_2. Increase in scores ā 2.136 (36.714% increase).

Increase may be due to either intervention X or sensitisation (Anastasi 1958)

Figure 2

The single most noticeable observation to appear from the comparison of data was the large increase from pre-test to test calculated as 36.714 %. Taken on its own this figure indicates a high improvement in scores from pre-test to test, however any sensitising effect described by Anastasi (1958) had to be taken into consideration before a measure of the intervention and a "true" score of O_2 was possible (figure 2).

3.2 Data analysis: Control Group One Results

The main aim of control group one was to determine how much sensitisation was present between the pre-test and test without the intervention and to subtract this figure from the experimental group O_2 figure to determine a true value of the intervention X. Eight participants took part in control group one. This control group was given the same pre-test as the experimental group without any intervention being applied. Results were added and mean average RO_3 scores calculated, these being 8.125, three weeks later control group one were given the test without the intervention (full spectrum fluorescent lighting) and O_4 scores calculated as being ā 8.375. The mean average increase of 0.25 between the two data sets was used to determine a percentage increase from pre-test to test and was calculated to be 3.07% (figure 3) which was deducted from the experimental group result O_2.

RO_3 ā 8.125	**No Intervention** →	**O_4** ā 8.375

Three week interval between RO_3 and O_4. Increase in scores ā 0.25 (3.07% increase).
This figure represents sensitisation (Anastasi 1958) and will be deducted from O_2 score figure 2.

Figure 3

3.3 Data analysis: Control Group Two Results

The main aim of Control Group two was to provide a measure of the intervention X to compare with the 'true' figure ascertained from the experimental group data O_2. This control group was not required to take the pre-test, taking only the test with the intervention X being applied. Eight participants took part in control group two, the O_5 scores were added and a mean average score calculated as 7.125 (figure 4).

Intervention X applied	**O_5** ā 7.125

ā percentage increase was not possible with control group two.

No sensitisation (Anastasi 1958) was possible since only treatment X was applied.

Figure 4

4. Interpretation of Data

The aim of the study was to observe if intervention X would lead to improvements in concentration between pre-test and test. The majority of the data collected during this study was subjected to quantitative analysis. However to achieve a better understanding of the effect of intervention X, participant opinions were included to supplement the data collected from the Solomon Variant. Data obtained from this study indicate that test scores increased when participants were subjected to the intervention X (full spectrum fluorescent lighting) compared to the cool white fluorescent lighting used during the pre-test. Data suggests that when applying the intervention X to the experimental group, mean average scores increased by 33.644% after the effect of sensitisation described by Anastasi (1958) were subtracted from the test score (O_2). Data from this study also suggests that participants had mixed feelings about the effect of the intervention but these were generally positive constructive comments with only one negative data set.

When participants subjected to the intervention were asked to comment on pre-test and experimental lighting conditions 27% remarked that the intervention lighting was bright but not unpleasant and 27% thought that the pre-test lighting was not too bright or unpleasant. Additionally 22% thought that the intervention lighting helped them to see well and 13% from the same group felt that the intervention light was more natural. Moreover 13% of participants taking pre-test or test without the intervention X felt that the cool white fluorescent lighting caused them to feel more awake, 18% felt that the lighting was artificial and 22% thought that the lighting was responsible for giving them headaches. These findings while preliminary imply that personal perceptions of lighting conditions in the classroom may affect visual acuity according to the individual's physiological or psychological makeup with the potential to impact learning (Revel et al, 2006; Mills et al, 2007) and additional investigations, which take these factors into account should be undertaken (Boyce, 2003).

Prior to reaching any conclusions implied by one set of data, this study cross-referenced other data sets to support, disprove or question the reliability of data analysed from the experimental group O_2 score.

5. Conclusions and Recommendations

This paper investigated whether full spectrum fluorescent lighting impacted concentration of students in an active classroom. The research was conducted in a 'real' work situation using a sizeable sample size in comparison to previous studies which used laboratory type settings and very small sample sizes. Mills et al (2007) researching similar effects in the workplace setting noted that studies in this field outside the laboratory setting were uncommon and that lighting conditions researched outside the laboratory setting were not fully understood. Additionally Boyce (2003) draws attention to the fact that research in this field is still in its infancy suggesting that much more work needs to be undertaken to study the link between full spectrum light and alterations to cognitive functioning.

The particular emphasis of this study was to observe levels of concentration by using full spectrum fluorescent lighting (the intervention) during a non-verbal reasoning test. Although test scores improved when the intervention was applied, other causes for any increase should be considered such as; physiological alterations in the visual system or psychological adaptation to the test environment. Furthermore several limiting factors need to be acknowledged concerning this study: The size of the sample chosen was relatively small compared to the overall student population. One of the limiting factors with regard to sample size was the availability of participants due to the constraints of a busy timetable and the rate of experimental mortality where participants failed to attend the data collection. Other factors which affected the planning stages of this study were: permission to use student groups in the study, timetable space to allow students to take part at a time when the experimental area was available, personal work commitment, available time in which to undertake the data collection and the financial cost of providing resources required to conduct the experiment.

This study was able to replicate some of the findings of Mills, et al (2007) which indicated substantial changes to cognitive functioning as the result of using full spectrum fluorescent lighting, furthermore the results from this study were partially substantiated by the earlier findings of Vanderwalle (2009) in that cognitive functioning appeared to be affected through its use. Moreover, the current findings of this study indicate that student's perceptions of the learning environment being more appealing and enabling better visual acuity compared to previous lighting suggest a role for full spectrum fluorescent lighting in promoting work-based concentration. The empirical findings of this study indicate that further research to investigate the effect of full spectrum light on targeted groups rather than using random sampling may be useful. The current research was not specifically designed to evaluate student's behavioural or physiological issues, however further research may prove useful in determining the benefits of full spectrum lighting for use with dyslexic students or those with autism spectrum disorders (ASDs) and groups requiring learner support in the classroom. What is more the use of full spectrum light in the classroom may have far reaching consequences for teachers involved in teaching Special Educational Needs and Learner Support, simply because their cohorts are able to concentrate more during visually directed tasks in an environment enhanced by F.S.F.L. In terms of specialist support for these learners there is little evidence to demonstrate that current pedagogical strategies are failing to be effective, however the findings of this study indicate that F.S.F.L. used in selected teaching areas may facilitate a more comfortable journey through the classroom experience to that currently experienced by both student and teachers equally.

The conclusions of this study suggest that the use of full spectrum fluorescent lighting in schools and colleges may be prove to be beneficial in terms of student concentration and mood and may prove to be a viable way in which to reduce the pupil exclusion rate. Additionally this study found that participants felt happier and more inclined to focus more when exposed to full spectrum lighting, factors which Lavoie (2003) and Lockley et al. (2006) attribute to a reduction in alpha and theta brain activity responsible for lethargy and sleepiness. Such evidence suggests therefore that in the design of any learner environment serious consideration to full spectrum blue lighting should be given to provide optimal illumination for better visual acuity, and promote work-based concentration.

Conducted in a small classroom the data obtained from this study indicate that full spectrum lighting may have influenced levels of concentration and mood, furthermore it may be worth considering whether these findings could be applied to all small classrooms especially the austerity schools planned for the future. The Royal Institute for British Architects (2012) recently commented that the proposed 'austerity' schools are likely to deprive learners of a proven environment favourable to learning. In addition The British Council for School Environments (2012) expressed serious concerns that any internal shrinkage in space will lead to less flexible teaching areas with the result that innovation will be inhibited and smaller spaces for pupils may have an adverse impact on behaviour. Taken together, these findings suggest that using full spectrum fluorescent lighting may help in providing an environment more conducive to learning within existing classrooms and those planned for the future.

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PEDESTRIAN WAY LIGHTING: USER PREFERENCES AND EYEFIXATION MEASUREMENTS

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Abstract: *The International Commission on Illumination (CIE) established a Joint Technical Committee JTC-1 Implementation of CIE 191 System for Mesopic Photometry in Outdoor Lighting in January 2012. The first task of JTC-1 is to define visual adaptation field in outdoor lighting. This article focuses on pedestrian way lighting. The purpose of this article is to find out eye-fixation area/location which is helpful in defining the visual adaptation field. At first, this article reviewed previous studies related to size of visual field in different objects and different ages, eye tracking systems used in these studies. And then, investigations and measurements were carried out on a pedestrian way in Chongqing of China. Relationships between lighting conditions and user preferences were also analyzed. The SMI iView X HED eye-tracking system was used in this study. Five subjects participated in the investigation and measurement. Questions were asked for each subject. Videos were recorded for each one including eye tracking data such as fixation counts and dwell times while walking both forward and backward. Eye-fixation areas/locations were defined and analyzed based on the data. The conclusion is that the fixation area/location of the subjects were more concentrated around a central area in the horizontal level and were wider in the vertical level.*

Keywords: luminance, user study.

1. Introduction

The starting point of the work is the current task of CIE JTC-1 *Implementation of CIE 191 System for Mesopic Photometry in Outdoor Lighting*, which is to investigate adaptation and viewing conditions and define visual adaptation fields in outdoor lighting. Data needs to be collected based on luminance and eye-fixation measurements in varied outdoor lighting installations (road, pedestrian/bicycle, park etc.). This is one approach in determining the actual adaptation conditions in different situations and in defining visual adaptation fields in outdoor lighting.

This article focuses on pedestrian way environment. At first, the previous studies of visual field in walking conditions are reviewed; including size of visual field, the roles of foveal and peripheral vision and the difference of visual field between young and elderly walkers. In this work, experiments in Chongqing of China were carried out by using an eye-tracking system. User preferences for pedestrian way lighting were collected with the help of questionnaires. SMI (SensoMotoric Instruments) iView X HED eye-tracking system was used to record eye fixation data. The data was analyzed by BeGaze Software.

2. Review of previous studies

There have been only few studies focusing on visual adaptation in real pedestrian environments. Most of the studies related to the visual field in walking conditions have been conducted indoors (Stoffregen, 1985; Palta and Vickers, 1997; Holland s*et.al*, 2002; Itoh and Fukuda, 2002; Turon, 2005). The studies have focused on 1) the roles of foveal vision and peripheral vision to control posture or keep stance (Stoffregen, 1985; Turon, 2005); 2) the difference of eye movements between the young and elderly walkers (Itoh and Fukuda, 2002). Several eye tracking systems were applied in these studies (Palta and Vickers, 1997 and Itoh and Fukuda, 2002).

2.1 Sizes of visual field

Visual field contains foveal visual and peripheral visual field. Itoh and Fukuda (2002) referred that different estimations of the visual field in foveal and peripheral vision were based on the classification of retina in the book of The Retina (Polyak, 1941). In this book, Polyak classified the foveal visual field to extend up to 16°, and peripheral visual field to extend from the central 16° field outward. However, later studies have defined various extends for the foveal visual field. For example, Brandt *et.al* (1973) blocked the peripheral visual field and exposed the foveal visual field up to 60° for the research of fovea/periphery effect on ego-motion (Brandt *et.al*, 1973). Yoshida (1983) considered foveal visual field to only subtend the central 3° field, as more than 30% of the visual acuity capacity was within this field (Yoshida, 1983). In 1999, Bardy et.al considered foveal visual field to subtend 30° for the study of roles foveal and peripheral vision in postural control during walking (Bardy, *et.al*, 1999).

2.2 Objectives of the studies

The study conducted by Stoffregen (1985) verified that the peripheral visual field is dominant in controlling posture and keeping stance (Stoffregen, 1985). Turon (2005) pointed out that foveal and peripheral vision provide different types of visual information for walking. Foveal vision is associated with orientation and peripheral vision with detection. People can walk accurately to a goal depending on the orientation derived from the foveal vision, and also together with the head and eye position which means gaze behaviour (Turon, 2005). As a result, gaze behaviour is another important consideration in the visual field studies.

Hollands (2002) provided information on gaze behaviour associated with both keeping stance and changing the direction of movement (Hollands, 2002). In the study of gaze behaviour, an eye tracking system was used in the experiment by Patla and Vickers (1997) where observers were asked to walk towards and step over an obstacle in their walking path (Palta and Vickers, 1997).

Pelz (2007) studied oculomotor behaviour in two environments: natural one and artificial one. In this study, natural environment was defined as a wooded environment which has dense woods and the path is uneven. Artificial environment was defined as an outdoor environment whit apartments around, and with paved pathways. In these two environments, subjects performed free-viewing and walking tasks and fixation durations and saccade sizes were recorded. In addition, the fraction of time gaze was also analyzed.

2.3 The difference of visual field between young and elderly walkers

Itoh and Fukuda (2002) conducted two indoor experiments concerning visual fields of young and elderly subjects. In these experiments eye movements during walking were recorded, and walking cadence (the number of steps per minute) with and without peripheral vision restrictions were measured. The “Talk Eye” eye-movement analysis system was used to find out the gaze areas and the speed of eye movements while walking both for the young and elderly walkers. Itoh and Fukuda found out that the area of foveal visual field of elderly walkers was wider than that of the young walkers; whereas the speed of eye movements of young walkers was lower compared to the elderly ones. It was concluded that the differences are due to the losses of visual capacity accompanied with aging (Itoh and Fukuda, 2002).

2.4 Eye tracking systems in the past studies

In the studies above, two types of eyetracker systems were used. Patla and Vickers (1997) used the Applied Sciences Laboratories (ASL) 3100H Eye View tracker, and Itoh and Fukuda (2002) used the “Talk Eye” eye-movement analysis system.

The Applied Sciences Laboratories (ASL) 3100H Eye View tracker is a mobile helmet. This is a monocular corneal reflection system that measures eye-line-of-gaze with respect to the helmet. The helmet has a 30-m cord attached to the waist, interfaced to the main computer, thus permitting near normal mobility of the participant. Miniaturized optics (scene and eye camera), an illuminator, a solid-state sensor, a relay lens, and a visor were mounted on the helmet, with a total weight of 700 g.

The “Talk Eye” eye-movement analysis system is manufactured by Takei Scientific Instruments Co., Ltd. It is a goggle containing a small infrared sensor recording the eye movements while walking by means of the infrared limbus tracking method. The eye movements are recorded by a camera to capture an optical image using an output digital signal. The camera is attached at the midpoint of the goggles.

3 Experimental set-up

The experiments of this work were carried out in September 2012. The study focuses on two issues: the relationships between lighting conditions and user preferences collected by a questionnaire, and eye-fixation areas/locations of the subjects while walking.

3.1 Pedestrian way

The test location is Sixian Road pedestrian way in Chongqing China, Figure 1. The lighting is provided by LED luminaires which replaced the high pressure sodium lamp luminaires in 2011. The parameters of the lighting installation are given in Table 1.

Figure 1 Pedestrian way (Sixian Road) in Chongqing China.

Table 1 LED installation of Sixian Road in University Town of Chongqing

Location	Sixian Road, university town Chongqing, China
When installation made	2011
LED-luminaire	LM-DL1015-135W
Luminaire Power	135 W
Luminous Flux	11 000 lm
Luminous Efficacy	>80 lm/W
Colour Temperature	5 500～6 000K
CRI	≥70
Pole Height	10 m
Pole Spacing	30 m

The illuminance and luminance measurements were carried out in the area between two poles, this is 30 m in length and 3 m in width. Thirty measuring points were spaced evenly in this field according to EN 13201-3: 2003, as shown in Figure 2 (CEN, 2003). The direction of measurements is from west to east. Eye tracking data was collected from five subjects while they were walking the pedestrian way, first to one direction and then back to the other direction. All subjects walked straight along the central line. After this the subjects walked the same way again before filling the questionnaires.

3.2 Illuminance and luminance measurements

The illuminance meter used was XYI-III illuminance manufactured by Mydream Electronic in China. The other illuminance meter was XYI-III semi cylindrical illuminance meter produced by Yiou Electronic in China.

The luminance meter was LM-3 luminance meter produced by Everfine in China (Figure 3, on the right). The aperture of 1° was used in the luminance measurements.

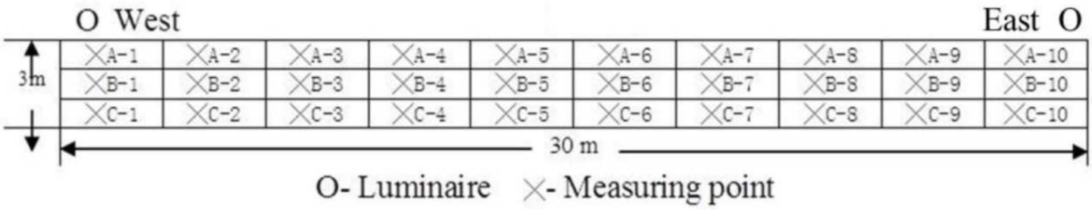

Figure 2 Measuring points on the pedestrian way.

Figure 3 Illuminance meter, semi-cylindrical illuminance meter and luminance meter used in the study.

Illuminance and luminance measurements were carried out in the evening between 19:30 p.m. to 22:30 p.m. As the University town in Chongqing is a developing area, the traffic and pedestrian volume on the road were not heavy at that time. The pavement of the pedestrian way is cement. The horizontal illuminances were measured at the road surface and the semi-cylindrical illuminances at the height of 1.5 m (the photo-cell faced both eastward and westward at each measuring point). The height of the luminance meter was 1.5 m. The measurement results are shown in Table 2. The average illuminance was 13.9 lx and the average semi-cylindrical illuminance 6.0 lx and 5.4 lx, eastward and westward respectively. The average road surface luminance was 0.49 cd/m^2.

3.3 Questionnaire

Five subjects aged 25-35 years, two males and three female, participated in the survey. Their colour vision and visual acuity were tested to be normal before the experiments.

The Colour Vision Test developed by Kechang Wang (Wang, 2001) was used. Visual acuity was tested with the Lea numbers near vision chart.

The questionnaire composed of two parts including basic information and the actual questions (Appendix A). Basic information included the gender, age, studying/working field, and the regularity of using the pedestrian way used in the study. The studying/working fields of the subjects are related to construction area and all of them were to walk for the first time on the pedestrian way.

Table 2 Illuminance and luminance values

Date: 28.9.2012				Time: 19:30-22:30			Weather: Cloudy			Place: Sixian Road		
Direction: West-East				Pavement: Cement			Lighting conditions: see Table 1					
Pedestrian's volume: Light							Traffic volume: Light					
If side walking plants: Yes							If business or advertising: No					
	E_h(lx)			E_{sc}(lx)(Eastward)			E_{sc}(lx)(Westward)			L_{ave} (cd/m2)		
Point	A	B	C	A	B	C	A	B	C	A	B	C
1	5.63	15.52	10.11	4.53	3.78	4.08	4.71	4.23	4.57	0.150	0.565	0.412
2	2.52	13.57	11.41	3.53	3.72	3.31	2.43	5.71	4.95	0.064	0.500	0.405
3	14.78	14.63	12.12	3.80	3.22	3.45	8.03	6.67	5.70	0.462	0.432	0.302
4	14.99	15.18	13.96	5.82	4.22	3.25	7.11	7.97	6.51	0.632	0.629	0.420
5	18.95	16.88	14.17	10.00	8.42	5.59	11.02	9.56	6.95	0.778	0.663	0.556
6	16.78	16.70	14.79	10.27	9.21	7.81	10.16	8.02	5.49	0.718	0.632	0.486
7	16.27	13.71	10.19	8.99	7.46	6.62	5.95	4.49	3.31	0.768	0.633	0.439
8	15.42	13.89	11.45	8.25	6.90	6.19	3.41	2.93	2.95	0.579	0.433	0.347
9	18.47	15.21	12.66	8.14	6.80	6.14	3.46	2.82	2.87	0.502	0.440	0.345
10	16.44	18.18	13.14	5.78	6.15	5.40	2.96	3.65	3.10	0.526	0.464	0.355
Ave.	13.9			6.0			5.4			0.49		

The Questionnaire included ten questions related to the general feeling of walking on the way; the feeling of pavement; lighting conditions including light level, light distribution, colour of light, glare, feeling of safety and facial recognition. The subjects provided their answers on a five-point scale.

3.4 Eye-tracking system

The SMI iView X HED eye-tracking system by SensoMotoric Instruments (SMI) was used in the experiments, Figure 4. The eye-tracking camera is installed in a helmet. The iView X workstation runs the iView X software and contains the hardware components that allow the system to capture eye movements. This workstation controls the camera equipment and processes the eye and scene video signals. The iView X workstation is used to control the camera system, to trigger events, such as calibration, drift correction, and the duration of the recording (SMI, 2007).

4. Results

4.1 Questionnaire

A five-point scale was used to fill in the questionnaire. In analyzing the results, each point of the scale was assigned a number (-2, -1, 0, 1, 2). The individual results and the weighted average values of these for each question are shown in Table 4. The weighted average values are calculated by Equation 1:

$V = [\sum_{i=1}^{n} W_i T_i]/\sum_{i=1}^{n} W_i$(n=1,2,3,4,5) (1)

Where:

V - Weighted average;

T_i- Value of each question on the scale -2, -1, 0, 1, 2;

W_i- Number of subjects choosing the according value (T_i).

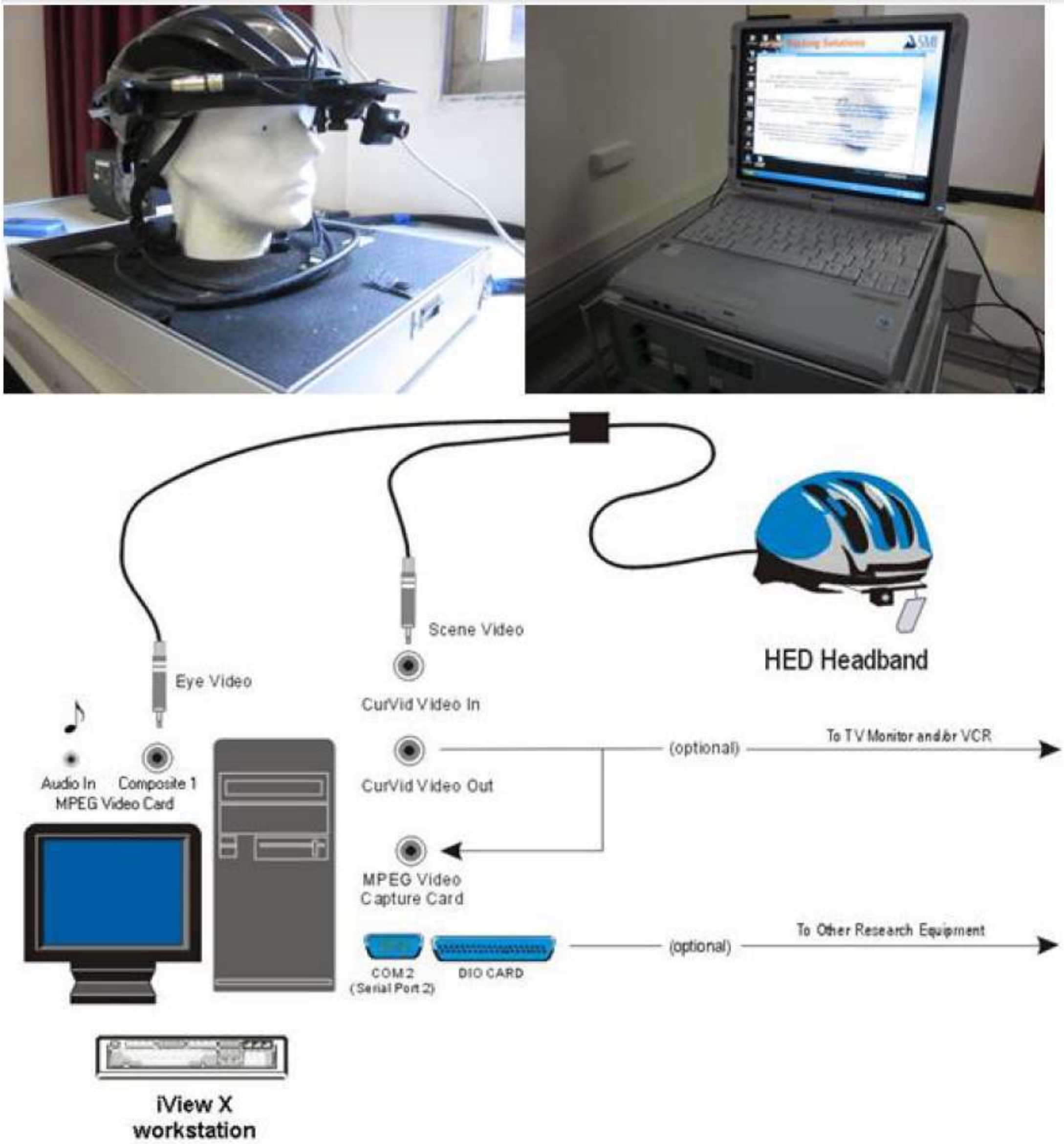

Figure 4 SMI iView X eye tracking system.

Table 3 Illuminance and luminance values

Questions	T_i					V
	-2	-1	0	1	2	
1. Feeling of pavement	0	2	0	3	0	0.2
2. Feeling of light level	0	4	1	0	0	-0.8
3. Feeling of lighting distribution	1	1	1	2	0	-0.2
4. Feeling of colour of light	0	2	2	1	0	-0.2
5. Glare	No glare					-
6. Feeling of walking after dark	0	3	1	1	0	-0.4
7. Importance of lighting for movement	0	0	0	1	4	1.8
8. Importance of lighting for safety	0	0	0	0	5	2.0
9. Feeling of facial recognition	1	1	1	1	1	0
10. General feeling of walking on this street	0	2	1	1	1	0.2

4.2 The relationship between lighting conditions and user preference

Pedestrian way lighting is built to increase the feeling of safety and to enable facial recognition (CIE, 2000; CIE, 2010). According to CIE (CIE, 2010), lighting criteria of pedestrian ways include values for average horizontal illuminance $E_{h,av}$, minimum horizontal illuminance $E_{h,min}$. In addition, values for minimum vertical illuminance $E_{v,min}$ and minimum semi-cylindrical illuminance $E_{sc,min}$ are given as additional requirements related to facial recognition. Table 5 summarizes the relationship between lighting conditions and questionnaires (Value of evaluation, V) according to the requirement in CIE 115: 2010. Minimum vertical illuminances $E_{v,min}$ were not measured in this experiment.

The weighted average for responses related to the pavement material is $V = 0.2$, indicating that the subjects felt neutral for the pavement material. The same was found for the light distribution, colour of light and feeling of facial recognition. However, the subjects strongly felt, that lighting is important for movement and safety.

The average horizontal illuminance was 13.9 lx, which the subjects found to be a bit too low light level with $V = -0.8$. Glare was not experienced by any of the subjects. For enabling facial recognition the recommendations provide minimum semi-cylindrical illuminance values of 2.0 lx and 3.0 lx. The measured value was 2.43 lx and the subjects responses for feeling of facial recognition were neutral ($V = 0$).

In general, the lighting conditions of the pedestrian way were not negatively experienced.

4.3 Eye-tracking measurements

The eye-tracking data was analyzed by the BeGaze Software, which is a software for behavioural gaze analysis and analyzes visual attention and visual search patterns. Visual and analytical data of eye gaze, eye movement and pupil data can be reviewed e.g. by scan paths, areas of interests (AOIs), and quantitative analysis on fixation and saccades.

Table 3 Lighting-related questions in the questionnaire, lighting parameters and recommended values for pedestrian ways (CIE, 2010), measured values and the weighted average (*V*) values of the responses

Questions	Parameters (CIE, 2010)		Recommended values (CIE, 2010)		Measured values	*V*
1. Feeling of pavement		Pavement			cement	0.2
2. Feeling of light level	Horizontal Illuminance		P1*	15lx	13.9lx	-0.8
			P2*	10lx		
3. Feeling of lighting distribution	Uniformity				0.2	-0.2
4. Feeling of color of light	Color rendering				≥70	-0.2
5. Glare	Glare	Feeling of safety			NO	-
6. Feeling of walking after dark						-0.4
7. Importance of lighting for movement						1.8
8. Importance of lighting for safety						2.0
9. Feeling of facial recognition	Minimum semi-cylindrical illuminance	Facial recognition	P1	3.0lx	2.43lx	0
			P2	2.0lx		
10. General feeling of walking on this street						0.2

*P1 and P2 are the lighting classes for pedestrian and low speed traffic areas (CIE, 2010).

In this work fixation areas/locations are reviewed by scan paths and gridded AOIs. Reference views were defined in a custom trial selector and fixation points were mapped in semantic gaze mapping. Pictures of reference views were selected from the 5-10 m, 10-15 m, 15-20 m and 20-25 m areas along the pathway, each for two walking directions, this is altogether eight reference views for each subject. Each reference view has different gridded AOI data according to the videos with semantic gaze mapping, that is scan path.

The gridded AOI data includes fixation counts and dwell times. Before collecting data, one important procedure is to customize trails with different reference views.

4.3.1 Scan paths

The scan path data view shows gaze position and eye-tracing of the selected reference view. The scan path main view visualizes the selected trials data sets as a 2D plot over the reference views. Due to eye blinking, the fixation count and dwell time data is not continuous but jumpy.

Figures 5 and 6 show the data of one subject in eight reference views; this is fixation and saccade plots with dynamic fixation radius. Fixation radius is related to the duration of fixations. Most of the fixation counts concentrate on the pavement.

Figure 6 shows examples of fixation and saccade plots with dynamic fixation radius in the same reference view for four subjects.

Figure 5 Scan paths of one subject during walking the route in one direction.

The selected reference view is in the 10-15 m area along the walking path. The average road surface luminance of this area is L_{ave} = 0.49 cd/m^2. The fixation points of the subjects are condensed within the horizontal level but wider in the vertical level.

Figure 6 Scan paths of reference view for four subjects.

4.2.2 Gridded AOIs

The areas of interest (AOIs) were gridded in each reference view. Reference views were created for both walking directions for each subject. Due to the experienced recording errors of one subject, data was analyzed only for four subjects. Figures 9 and Figure 10 show examples of total dwell times and fixation counts in a reference view described by a grid of AOIs. The image shows an 8×8 grid. Dwell time, whit unit of milliseconds (ms), is the sum of all fixations within an AOI for the selected reference view; fixation count is the number of all fixations for selected subjects (SMI,2012).

Figure 9 shows raw data of the total dwell times and fixation counts for four subjects for the reference view (between 10-15 m on the pedestrian way) while walking to one direction. The longest dwell time or highest number of fixation counts of each subject is marked in red.

The results indicate that the dwell time areas are not necessarily the areas having most fixation counts. For example, subject 1 (S1) in row 5/column 5 has highest fixation count of two times but a short dwell time of 299.1 ms.

Subject 4 in turn has the longest dwell time of 2134.2 ms but only six fixation counts in row 5/column 5. For this subject, the most fixation counts are found in row/column/, where there are nine fixation counts.

Figure 7 Dwell time (ms) described by AOIs of a reference view for four subjects.

Figure 8 Fixation counts described by AOIs of a reference view for four subjects.

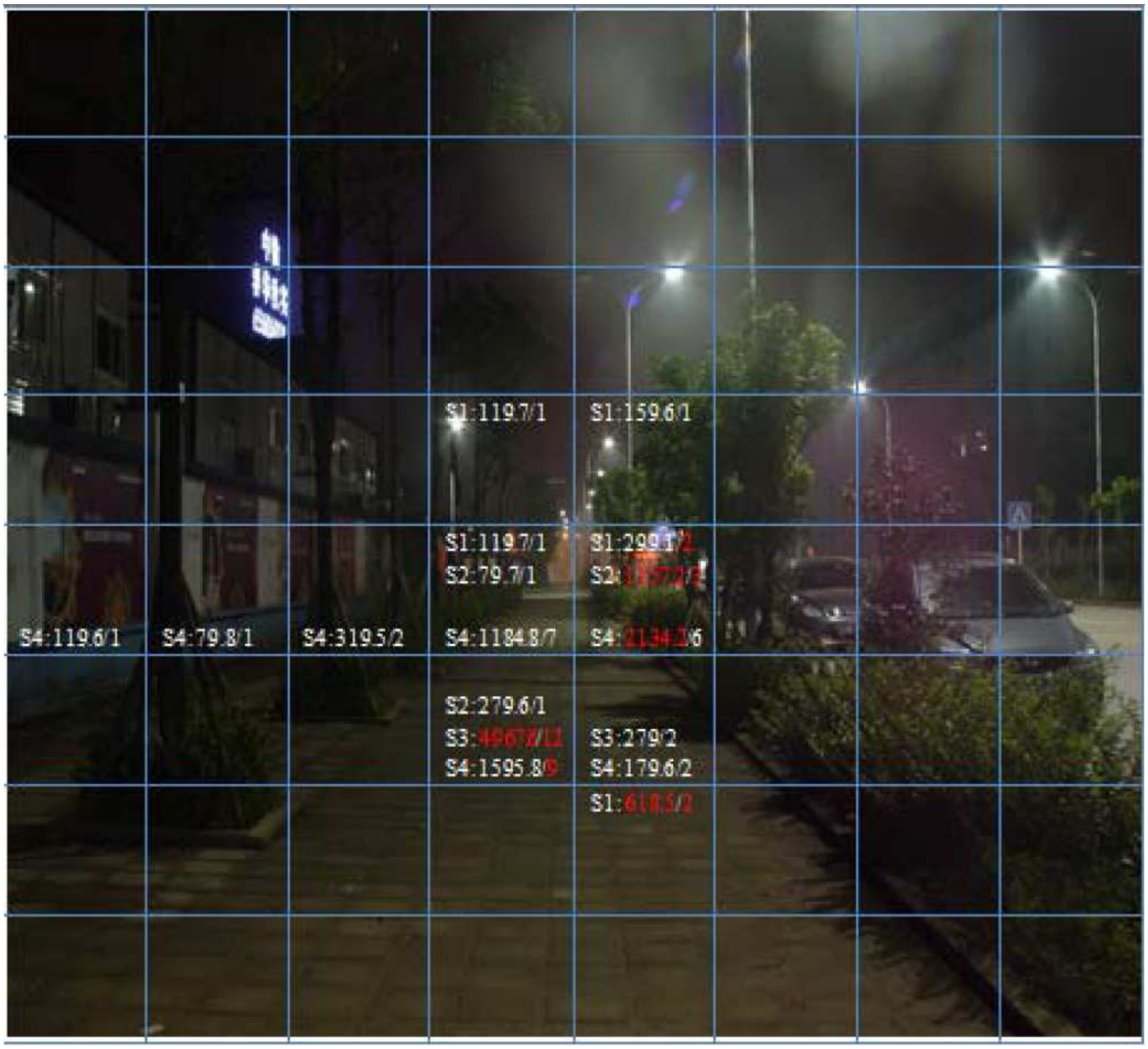

Figure 9 Total dwell times and fixation counts in gridded AOIs for four subjects S1-S4.

5. Discussion and conclusions

The user survey indicated that people find pedestrian way lighting to be especially important for movement and safety. In this study, they did not find facial recognition to be important. Davoudian and Raynham found out that the importance of facial recognition depends on the specific visual tasks at different light levels (Davoudian and Raynham,2012). In this study people were neutral in their opinions about the easiness/difficulty of facial recognition on the specific pedestrian way.

During eye-tracking recording, it is hard to avoid blinking of the eyes, so the recording of fixation counts and dwell times is not continuous. The measurements do, however, illustrate that most of fixation areas/locations focus on the road surface.

The average road surface illuminance of the pedestrian way of this study (13.9 lx) fulfils the requirements of the S2 class (10 lx) and is close to the S1 class (15 lx) (CIE, 2010).The average road surface illuminance of 13.9 lx meets also the recommendation of 10 lx in the Chinese guidelines (CJJ 45-2006). In their study, Davoudian and Raynham (2012) concluded that on a pedestrian way with illuminance meeting the S1 class, pedestrians feel less insecure and can thus spend more time looking at the footpath. This supports their argument that at higher illuminance level pedestrians feel more secure and thus do not pay too much attention to threats in the environment.

The fixation areas of the subjects were more concentrated around a central area in the horizontal level and were wider in the vertical level. In analyzing the eye tracking data it is important to consider both the dwell times and fixation counts. It was found that the areas with the longest dwell times are not necessarily equal to the areas with most fixation counts. That is, in considering the areas of interest (AOI) in studying the visual adaptation field, both the dwell times and fixation counts need to be taken into account.

In this study, the eye-tracking system consisted of a helmet that the subjects were wearing. The helmet needs to be fixated strictly on the subject's head after calibration. To some extent, this may limit the subject's behaviour during walking. Another choice would be to wear eye-tracking glasses to record the fixation data while walking. Whit the glasses the subjects would feel more natural while recording the data. Further studies could also combine eye-fixation data with pupil size and luminance data. This would help in studying the adaptation conditions of the road users.

6 Acknowledgements

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7 Appendix A - Questionnaire

Date: Time:
Place:

Basic information

Gender: Male □Female □
Age:
Studying/Working field:
Visual acuity check: Normal □Abnormal□
Colour vision test: Normal □Abnormal□
The street I walked, the first time today.□
few times a year. □
few times a month. □
few times a week. □
every day. □

Questions

1. How do you feel about the pavement of this street?

Very unpleasant□□□□□Very pleasant
–2 –1 0 1 2

2. How do you feel about the lighting on this street?

Too dark□□□□□Too bright
–2 –1 0 1 2

3. How do you feel about the lighting distribution on this street?

Very non-uniform□□□□□Very uniform
–2 –1 0 1 2

4. How do you feel about the colour of light on this street?

Very unpleasant□□□□□Very pleasant
–2 –1 0 1 2

5. Do you perceive glare on this street?
Yes □No □
If yes, how do you feel the glare affects you?
Very unpleasant□□□□□Very pleasant
–2 –1 0 1 2

6. How do you feel while walking alone this street after dark?
Very unpleasant□□□□□Very pleasant
–2 –1 0 1 2

7. How important do you feel lighting for moving easily on this street after dark?
Not important□□□□□Very important
–2 –1 0 1 2

8. How important do you feel lighting for feeling of safety on this street after dark?
Not important□□□□□Very important
–2 –1 0 1 2

9. Do you find facial recognition on this street
Very difficult□□□□□Very easy
–2 –1 0 1 2

10. How do you feel generally while walking on this street after dark?
Very unpleasant□□□□□Very pleasant
–2 –1 0 1 2

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TOWARDS THE FORTH EPOCH OF COLORIMETRY

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Abstract: *Colorimetry, as mathematically describable science, was born in 1931, when CIE accepted a system of colour matching functions, three standard illuminants and the rules of colour matching. During the next decades the technique of colour matching and colour difference evaluation progressed, and by end of 20th Century colorimetists could direct their attention towards the description of colour appearance. At the same time – however – neurobiology made huge steps towards understanding the mechanism of human vision, not only on the retinal level, but regarding brain mechanisms. The better description of the cone spectral responsivities, understanding (at least partially) the mechanisms of the fifth light sensitive cell in the human retina, the intrinsically photoreceptive Retinal Ganglion Cell, and its role in vision, opened the possibility to better describe colour vision phenomena. The paper enumerates some of these and calls attention to further investigate these questions.*

Keywords: .

1. Introduction

The past Century of colorimetry can be can be divided into three main phases Before 1931 colorimetry was done by comparing the test sample to some reference samples (naturally the use of standard reference samples, e.g. samples from a colour order system has its proper application also presently, and will be used in the future as well, but ceased to be the only way to describe the colour of a sample).

In 1931 CIE standardized a method of colour matching to the additive mixture of three properly selected fundamental stimuli, so that one can describe the colour by the proportions of the three fundamental stimuli used to match the test colour[1]. During the following 60 years this system was further elaborated, two sets of imaginary colour matching functions (CMFs) have been defined[2], the system of standard illuminants has been extended[3], detailed descriptions for colorimetric practice, calculation of colour differences, etc. has been completed (see [4, 5]).

During the second half of this period the interest of colour scientists turned from describing colour matches and colour differences to the development of a mathematical correlate of colour appearance. The final outcome of this endeavour was the development of the CIECAM02 colour appearance model[6]. Based on this model the colour appearance of test samples can be described illuminated by any light source, taking chromatic adaptation into consideration. Naturally this model will be further fine-tuned; some amendments are already available (as e.g. a colour difference metric[7]), or are under development (e.g.[8, 9]).

During the past 20-30 years photo- and neurobiology progressed considerably. For the next epoch of colorimetry two such findings are of paramount importance: gene research has shown where and how the photopigment creation is coded, and the discovery of the mechanism of the intrinsically photosensitive Retinal Ganglion Cells (ipRGCs) points in the direction that they might have influence not only on the circadian rhythm of the human body, but also in vision phenomena. In the following some of these mechanisms and their consequences on colorimetry shall be discussed.

2. The fourth epoch of colorimetry

The forth epoch of colorimetry got triggered by the two biological findings: understanding the multitude of real CMFs and the fifths light sensitive cell in the human retina.

2.1. Diversity of colour matching functions

Two main visual experiments led to the CIE 1931 CMFs, those performed by Guild[10] and by Wright[11, 12]. Based on their results a transformation was performed, so that one of the CMFs became equal to the spectral luminous efficiency (*V(λ)*) function of photometry. Unfortunately the CIE 1924 *V(λ)* function is in error in the blue part of the visible spectrum[13], and this produced errors in the CMFs as well. CIE established a technical committee ”to study this problem and to establish a chromaticity diagram of which the coordinates correspond to physiologically significant axes”[14]. This technical committee investigated thoroughly all the experiments published on the CMFs, and came to the conclusion that the best experimental data are those published by Stiles and Burch[15]. Based on these data, considering the absorption characteristics of the different ocular media, and supposing the validity of the König hypothesis (that the cone spectral responsivities of the three cone types (low-, medium-, and short wavelength sensitivity cones) are the same in case of trichromatic and dichromatic observers; this is needed to be able to transform from RGB CMFs to cone fundamental CMFs), the committee prepared $\bar{l}(\lambda)$, $\bar{m}(\lambda)$, $\bar{s}(\lambda)$ cone fundamental based CMFs, both for the 2° and the 10° observer[16].

Based on these CMFs TC 1-36 prepared the following transformation to an XYZ like form called fundamental based CMF (to the best knowledge of the author this transformation has not been finally agreed yet)s:

$$\begin{pmatrix} \bar{x}_F(\lambda) \\ \bar{y}_F(\lambda) \\ \bar{z}_F(\lambda) \end{pmatrix} = \begin{pmatrix} 1{,}94735665 & -1{,}41445201 & 0{,}36476092 \\ 0{,}68990272 & 0{,}34832189 & 0 \\ 0 & 0 & 1{,}93485340 \end{pmatrix} \begin{pmatrix} \bar{l}(\lambda) \\ \bar{m}(\lambda) \\ \bar{s}(\lambda) \end{pmatrix}$$

Figure 1 shows the traditional CIE 1931 (2°) and the cone fundamental based CMFs.

Similar CMFs have been established for the 10° observer, see Figure 2. As can be seen from the comparison of the two figures, the "errors" in the CIE 10° functions are much smaller than in the 2° functions. This will be important when we deal with colour rendering.

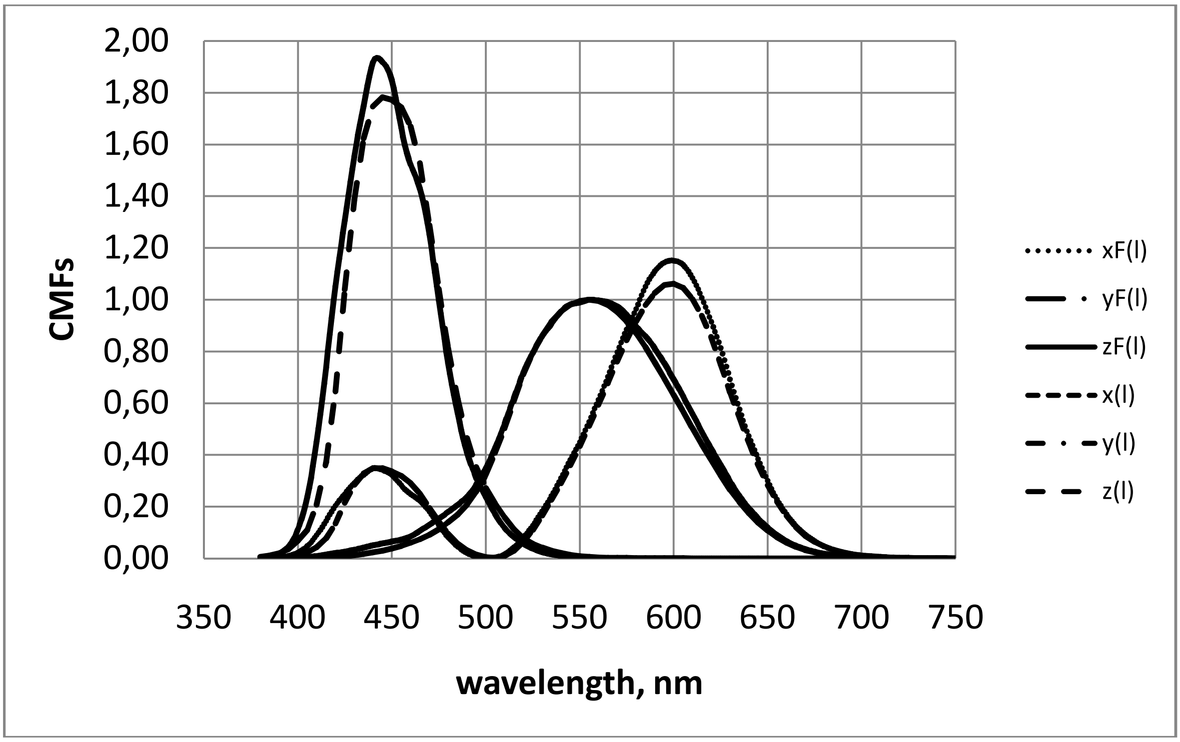

Figure 1 CIE 2° and cone fundamental based colour matching functions.

Visual experiments have shown that if the colour of broad-band white or bluish stimuli are matched with that of RGB LEDs, Δ (*u'*, *v'*) chromaticity differences in the order of 0,05 are observed. Using the cone fundamental based CMFs these errors are halved or even made smaller[17] (this publication shows that even better CMFs can be obtained with a small displacement of the $\bar{z}(\lambda)$ function, but this has still no photobiological underpinning).

It will be the task of the forth epoch of colorimetry to use the cone fundamental CMFs in colorimetric practice. It is out of question that the colour of LEDs is better described by these CMFs, but how they would function in colour difference and chromatic adaptation transformation equations as well as in colour appearance models has to be investigated.

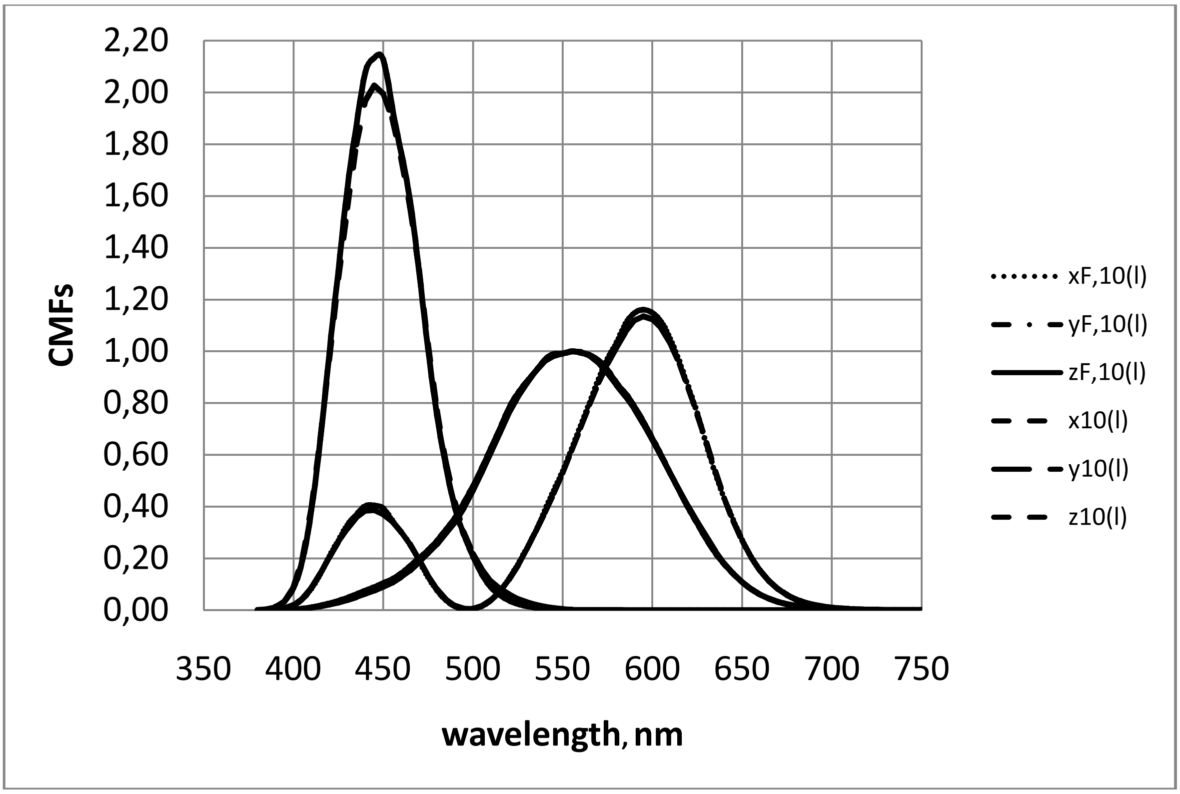

Figure 2 CIE 10° and cone fundamental based colour matching functions.

The CIE described only one – average – cone fundamental based CMF set. But voices get heard that individual differences might need been considered as well. In film and TV studios several technicians are working on a production, who might use different displays and might have slightly deviating spectral sensitivities, and this might lead to confusion in the colour correction work[18]. From molecular genetics research one has a clear picture of what produces small photopigment spectral absorption differences. Jeremy Hathans and co-workers have determined the sequencing of the long-, middle- and short-wavelength sensitive cone photopigment opsin genes[19]. Hybrid or mixed L and M-cone genes are leading to slightly different spectral absorptions. By the help of molecular genetics investigations, persons with different cone spectral absorption characteristics can be identified.

Sarkar came – via a different route – to similar results based on the raw data obtained by Stiles and Burch for the 10° observer and his own experiments. He concluded that his observers could be subdivided into eight main classes with different CMFs. The eight sets of CMFs are shown in Figure 3.

Comparing these with the CIE TC 1-36 10° observer curves interesting differences are seen in the function. Sarkar found similar differences as Csuti[17], and these are partially contradicting the conclusions of CIE TC 1-36.

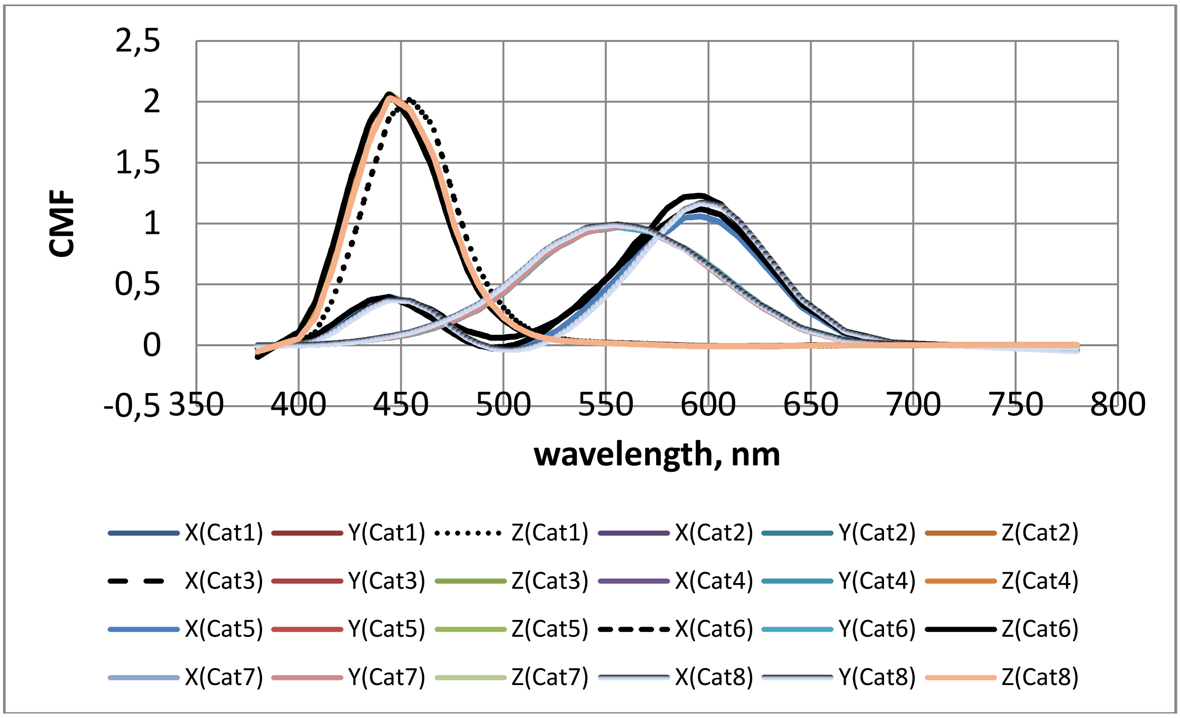

Figure 3 CMFs of Sarkar's eight observer categories.

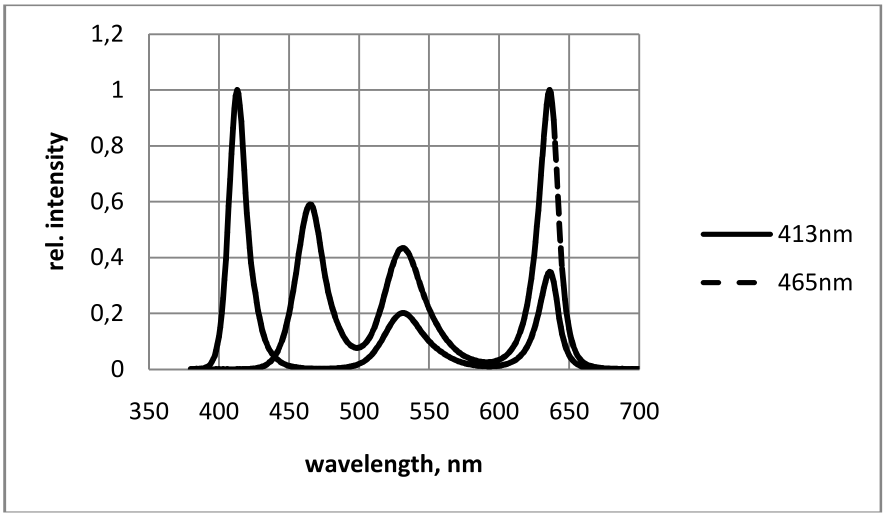

Figure 4 Spectra of the two RGB white LEDs.

To see the effect of these variations in the CMFs, two RGB LEDs were selected producing chromaticity equal to that of a D65 simulator, and calculated the chromaticity for these spectra using the two most extreme CMFs of Sarkar's collection (Cat.1 and 6), as well as the CIE TC 1-36 recommended cone fundamental based CMFs.

Figure 4 shows the spectra of the two RGB white LEDs that have a chromaticity equal to that of CIE D65 illuminant. The R and G stimuli are produced by the same LEDs in the two cases, the blue LEDs are changed, the curves are labelled by thewavelength maxima of the two blue LEDs used.

If chromaticity is calculated with these spectra, using the two Sarkar CMFs and the CIE TC 1-36 cone fundamental based CMFs, widely different values are obtained, see Figure 5.

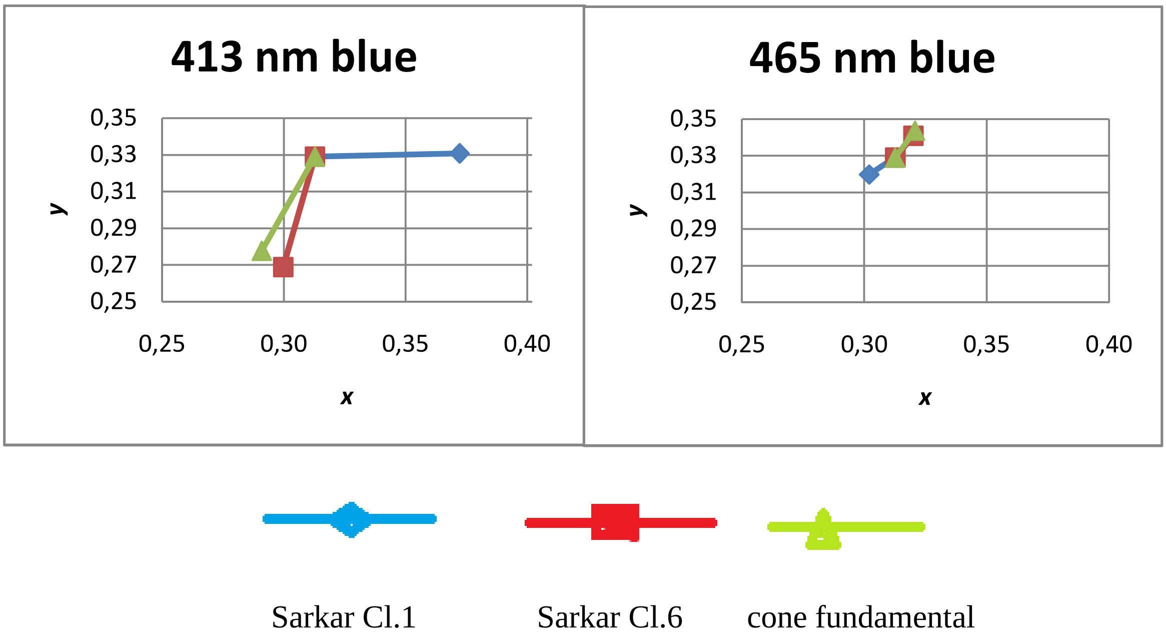

Figure 5 Chromaticity, calculated using different CMFs.

As can be seen, if a blue LED with a maximum at 413 nm is used, differences are huge, but even with the 465 nm maximum blue LED the differences are in the second decimal of the chromaticity, in the white part of the chromaticity diagram this is well visible. Interesting enough even the direction of the chromaticity changes is different if one or the other of the two blue LEDs are used. The use of the 413 nm blue LED is certainly an extreme choice, but blue LEDs are often found in the 450 nm to 480 nm range, and differences, as shown in the right side figure of Figure 5, are thus quite common. Using modern LCD monitors with LED backlighting such situation can occur, and if operators with different colour perception work in a team this can lead to problems, just as if one operator has to use LCD monitors with different LED backlights.

2.2. Influence of the fifth light sensitive cell

The intrinsically photosensitive Retinal Ganglion Cell (ipRGC) was discovered in the mammalian retina as early as in first Quarter of the 20th Century[20], but was rediscovered during the last decade of the 20th Century[21]. It was shown that the melanopsin photopigment in these cells (a small part of all the well known retinal ganglion cells that transmit the signals received from the photoreceptors – after modification by other cell types – to the brain) absorbs in the blue part of the spectrum and contributes to the synchronization of the circadian rhythm of the human body.

It turned out – however – that the stimulation of the ipRGCs influences not only the circadian rhythm, but also the pupil light reflex[22]. Recently Zaidi and co-workers have shown that the ipRGCs "contribute to both circadian physiology and rudimentary visual awareness in humans and challenge the assumption that rod- and cone-based photoreception mediate all "visual" responses to light"[23]. This will certainly open new ways to deal with the still existing discrepancies of many colorimetric and photometric observations.

One critical issue is the brightness-luminance discrepancy. Luminance is only a very first approximation of brightness. Deviations from a linear relationship are twofold: coloured lights seem to be brighter than achromatic lights of the same luminance (Helmhotz-Kohlrausch effect), see e.g.[24], and at low light levels rod intrusion influences brightness perception. CIE has published a report that takes both effects into consideration and defines how an equivalent luminance of the brightness perception can be calculated[25]. Based on this model the brightness of white lights should correspond to luminance well. Unfortunately this is not always the case.

Houser summarized the most important brightness description functions based on opponent colour models, and came to the conclusion that their brightness prediction ranks general-purpose white light sources similarly, and provides a better description than luminance[26]. Fotios, in a three-part paper, investigated the models for interior space apparent brightness, based on gamut area[27] and rod contribution, and suggested, instead of rod contribution, the effect of S-cones[28]; in the third paper he came to the conclusion that "at suprathreshold levels the achromatic channel is suppressed, and the brightness can be modelled adequately by the two chromatic channels alone"[29].

Berman and co-workers[30] described the phenomenon by the contribution of rod vision; but as the role of the ipRGCs became known models have been put forward that suppose a direct or indirect (via pupil diameter) influence of these[31], but see also[32].

In a series of studies we could show that none of the existing models describes the brightness perception of white lights correctly[33, 34, 35]. Observers could be classified into three major groups, who perceived white light of the same correlated colour temperature containing short wavelength blue light as brighter, equal or dimmer as predicted by luminance. Further research is needed, based on findings of the individual differences in the CMFs of the observers, the indirect effect of the ipRGCs, where they influence the pupil diameter, and this is not proportional to luminance, but is governed by a shorter wavelength mechanism (maximum sensitivity around 480 nm), and eventual direct contribution of the ipRGC signal in the spatial brightness perception. In this respect a further complication might occur: the contribution of the ipRGCs will be certainly not highly spatially selective, and thus might increase the brightness perception, but at the same time act as a veiling luminance and decrease contrast sensitivity.

2.3. Application of the new findings

Regarding the applications of the above new findings one of the central questions in applied colorimetry is the proper description of colour rendering. The CIE Test method of colour rendering[36] fails quite frequently in case of LED light sources[37, 38]. This is partly due to the fact that the CIE Test method is based on colorimetric know-how now 30-40 years old. Better chromatic adaptation models, more equidistant colour spaces, etc. are now available. Much knowledge has also been accumulated on the difference between colour fidelity and colour flattery (colour preference). Based on all these, CIE established two new technical committees for the study of colour fidelity and colour preference.

A latest model of colour fidelity[39] tries to use the most up-to-date colorimetric data and methods, such as the 10° observer (see Section 2.1), CIECAM02 colour appearance model[6], with the UCS colour difference formula[7], two sets of very special test samples, one to determine a general colour fidelity index and one to pinpoint the weakness of the source (to show in which part of the spectrum the lamp will provide poor fidelity of the object colours). Testing of the model is still under way.

3. Summary and conclusions

Colorimetry has done a long rout of progress from the purely visual inspections, via colour match calculation to the description of colour appearance, but with the two new findings of better average and individual colour matching functions and the influence of the intrinsically photosensitive retinal ganglion cells also in vision a new horizon opened up for research. If it will become possible to categorize the spectral sensitivity of the observers before experiments are started, one can hope that the big scatter in experimental results will shrink, and it will be easier to get to real average data, knowing also how large the individual differences might be if the method is used.

The real influence of the ipRGCs in vision is still not known, but one can expect that for some unexplained mismatches the influence of these cells might be responsible. One would need to know more about the action spectrum of melanopsin (non-additivity, depletion and regeneration effect)[40], possible individual differences (similar to those of the cone spectra).

As more fundamental knowledge will become available, colour science will certainly get again one step nearer to describe both average and individual colour perception.

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ERASMUS Intensive Programme 2012-2013

Lighting Design: state of the art and trends

Athens, June 24 – July 5, 2013

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LIGHTING DESIGN: STATE OF THE ART AND TRENDS
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What is an Erasmus - Intensive programme (IP)

An Intensive Programme - IP, is a short-term programme of study at a specific topic, which brings together students and academic staff from universities from different participating countries. The main IP objectives are to:

- encourage efficient and multinational teaching of specific topics,
- enable students and teachers to work together in multinational groups,
- gain new perspectives on the topic being studied,
- allow members of the teaching staff to exchange views on teaching content,
- test new teaching methods in an international classroom environment.

Universities involved in LiDe:

- Hellenic Open University - Patras, Greece
- School of Electrical and Computer Engineering, Lighting Laboratory, NTUA, Athens, Greece
- Georg-Simon-Ohm Hochschule fuer angewandte Wissenschaften - Fachhochschule Nuernberg, Germany
- Provinciale Hogeschool Limburg, Hasselt, Belgium
- Univerza v Ljubljani, Ljubljana, Slovenia
- European Union Centre, Izmir, Turkey
- Hacettepe Universitesi, Ankara, Turkey
- Universitatea Tehnică din Cluj-Napoca, Romania
- ENTPE, Vaulx en Velin, France

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- Universite Paul Sabatier - Toulouse III, France

What is the LiDe

LiDe aims at contributing to design issues using light (daylight or artificial light) as a design tool. The thematic area of lighting to be served by this IP is multidisciplinary. LiDe offers an intensive summer course on three thematic topics:

(i) Light & technology,
(ii) Light art & culture and
(iii) Urban master lighting planning. The course will include lectures and training.

The target group of the LiDe-IP consists of undergraduate and postgraduate students from various scientific disciplines (electrical and environmental engineering, architecture, designers and artists) and Universities across Europe. 32 students from 8 participating countries will attend the above IP-course. 5 ECTS will be awarded to the students that will successfully attend the course.

The main activities of LiDe concern an intensive summer school on Lighting Design as mentioned in the topics above. Each topic will consist of teaching (lectures) and training (experiments, computer simulation, Lighting-Design applications and team projects). Since LiDe is a design course mixed with knowledge on technology and physics, the final activity will consist of a team project where all knowledge acquired in the summer school might be implemented. In order for the summer school to run smoothly, careful design will be taken in advance, i.e., organization and administration of the LiDe, structure and contents of the summer course and finally the evaluation of the whole course.

Benefits

The main activities of LiDe concern an intensive summer school on Lighting Design as mentioned in the topics above. Each topic will consist of teaching (lectures) and training (experiments, computer simulation, Lighting-Design applications and team projects). Since LiDe is a design course mixed with knowledge on technology and physics, the final activity will consist of a team project where all knowledge acquired in the summer school might be implemented. In order for the summer school to run smoothly, careful design will be taken in advance, i.e., organization and administration of the LiDe, structure and contents of the summer course and finally the evaluation of the whole course.

The learning outcomes from the summer school are envisaged to be:

- the theory related to the topic, i.e., light/technology, light/culture, Lighting Design within urban areas,
- the training material related to the topic, i.e., the technology used in everyday lighting, the technology used in cultural applications, the methodologies used for urban areas.

Added value for students and teachers

The course will significantly contribute to a deeper knowledge in these new topics and scientific fields, adding value to the students, the teachers and the participating institutes. This can be achieved by the structure of the course and the topics chosen to be taught. As a result, the teachers will be given the opportunity to exchange ideas in common learning topics and achieve an advanced knowledge by the multilateral cooperation at this international context. This will lead to a better understanding of the structure of lighting design in other countries and will provide the advantage to upgrade and enrich the current modules taught at the institutes of the participating countries. In addition, the synergies expected to be developed, will lead to a stronger and long-lasting cooperation, enabling the opportunity for further cooperation in common projects, as, for example, the Erasmus central actions, curricula guidelines and thematic networks. In addition, the LiDe will improve the quality and significantly increase the volume of multilateral cooperation between higher education institutions. This will be fulfilled by the structure of the course, the participation of lecturers and the transnational cooperation among the institutes to be involved.

Participants

Students

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B- Michelle Rutten
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D- Thomas Berghofer
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F- Ikbal Marghad
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F- Keliang Hou
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GR- Aristotelis Vasiliadis
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F- Raphael Labayrade
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GR- Dimitrios Zevgolis
RO- Dorin Beu
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TR- Tayfun Taner
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GR- Konstantinos Pezoulas (Guest)
GR- Dimitrios Xintadekas (Guest)

Final word

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Ing.Horațiu Ciprian Armenean

REFURBISHMENT OF THE BUILDING SERVICES ENGINEERING FACULTY'S MAIN HALL LIGHTING SYSTEM

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1. Introduction

The Faculty of Building Services is the youngest faculty of the nine faculties within The Technical University of Cluj-Napoca. The Faculty's auditorium was built in 2009, after the entire building, has undergone a series of renovations. This auditorium is the largest one in the university, with a capacity of 300 people. The lighting system adopted in 2009 was based on luminaires using fluorescent lamps. After 4 years of utilization**,** the lighting system was refurbished.

The lighting system proposed in the year 2009 was with luminaires equipped with fluorescent lamps. After 4 years of using this system, in 2013 with the help of OMS company, we have changed the old solution-fluorescent lamps with the new solution-LEDs.

2. The classic lighting system equipped with fluorescent lamps

In this system we have used 61 luminaires based on 4xT8 18W fluorescent lamps, with a luminous flux of 4200 lm.

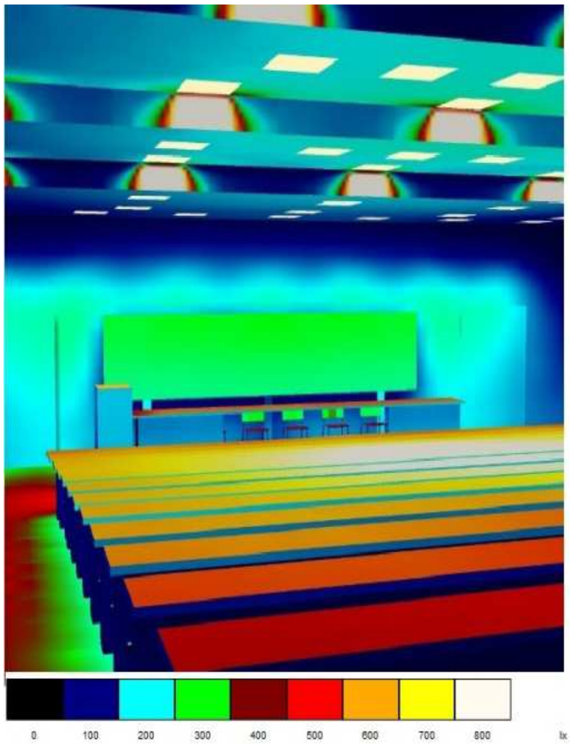

Figure 1 DIALux simulation with fluorescent lamps

The replacement of the classic system was determined by a series of factors, including also the average of illuminance of the blackboard which was around the value of 250 lx. Twenty luminaires were placed near the supporting structure of the auditorium (Figure 1). This arrangement had a negative influence on the luminous flux, because an important quantity of it was absorbed by the surface of the beams. The energy consumption was another factor, since a single luminaire consumed 84 W including the ballast, which means that the total amount of power installed was 5124 W. The maintenance costs have been estimated for a period of 10 years and the result was around 5000 Euros. In this estimation, we took into consideration the replacement of 8 lamps and 2 ballasts per luminaire.

An aesthetic deficiency of the system was a visible contrast between natural and artificial lighting.

Figure 2 The classic lighting system equipped with fluorescent lamps

The efficiency of the lighting system is established according to LENI coefficient. The system fits into efficiency class B, since the value of LENI is 43.40 kW/m^2·year.

3. The new lighting system equipped with LEDs

The adopted lighting system was proposed in collaboration with OMS company, a company from Slovakia. Cătălin Prahase, a former student of the Faculty of Building Services which now holds the position of Lighting Trend Manager at OMS company, managed to obtain for The Faculty of Building Services all the necessary equipments for the new lighting system.

The lighting ensemble uses 30 OMS GACRUX PV-1 OPAL LED luminaires and 5 AVIOR CONCRETE 40° LED spots. The GACRUX PV-1 OPAL LED luminaires are mounted in the recessed ceiling, each having a nominal input of 51 W, with a radiated luminous flux of 3550 lm. The AVIOR CONCRETE 40° LED spots have a nominal input of 31 W and a luminous flux of 2700 lm. The whole lighting system is controlled by a HELVAR 9240 touch screen panel through the DALI interface. It provides various possibilities of creating lighting scenes.

For example, in the case of a presentation, the system can be setup for an appropriate lighting scene (Figure 3) using the luminaires at different intensity. The luminaires are dimmed, so only the light from the spots is oriented on the speaker and the presentation surface. The light is a tool for the speaker during a presentation. An important factor when using a lighting scene for a presentation is the good vertical illumination of the presentation surface. In our case, we can provide vertical illumination through the spots which are mounted in front of the blackboard .

Another lighting scene can be created for full concentrated work. In this particular case, all the luminaires are working at full intensity. This level of illuminance sustains and promotes undisturbed work (Figure 4).

For the cleaning activities, energy can be saved by dimming the intensity of the light, since these types of activities don't require high light intensity, compared to a full concentrated work activity.

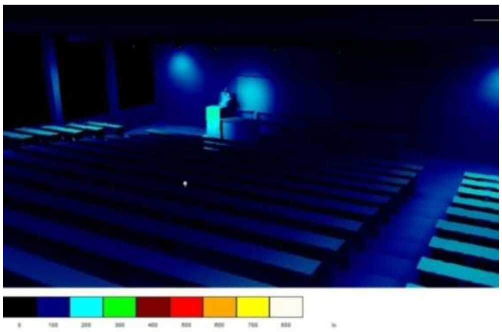

Figure3 Lighting scene for presentations (DIALux simulation)

Figure4 Lighting scene for full concentrated work

The new lighting system ensures a bright, comfortable, functional, and aesthetic environment. According to a recent study, attention span, concentration, and student behaviour are significantly improved by creating a dynamic lighting scene.

The total amount of power installed is 1685 W, a value that significantly reduces the cost of electricity. The power installed on the lighting system reduces with approximate 2.7 kW the necessity of the cooling air, required for the auditorium. The rooftop unit's coefficient of performance is 2.65, this means that the electrical energy consumed by the rooftop unit reduces with 1 kW.

The value of the LENI coefficient is 14.40 kW/m2·year, which fits the system into efficiency class A.

The average illuminance in different points of the work plan has been determined by measurements in approximately 400 points. The table below summarizes these values for both of the systems we have presented.

	Fluorescent lamps system		LED technology system	
Work plan	Average Illuminance [lx]		Average Illuminance [lx]	
Left Blackboard	253.5	249	460	465
Right Blackboard	256.2		469.0	
Central Blackboard	243.2		466.0	
Desks	525.0		436.7	
Floor	420.0		432.2	
Front desk	540.3		635.7	

Table 1 Values for the average illuminance in different points of work plan

4. Conclusion

We managed to ensure a good vertical illumination of the auditorium presentation surfaces (450 lx) by using a lighting system with an installed power of 1685 W and a total luminous flux of 130618 lm. The classic lighting system managed to ensure an average illuminance of 250 lx on the same presentation surface. We have to take into account that the system based on fluorescent lamps had a total amount of power installed of 5124 W and a total luminous flux of 207475 lm. Annual energy savings amount to 687.8 Euros, if we consider the price of electrical energy at 0.10 Euro/kW·h and 2000 operating hours per year. Maintenance costs for the lighting solution using LED luminaires are low or absent, compared to the maintenance cost of the lighting system using fluorescent lamps, which raised the costs to approximately 5000 Euros over a period of 10 years. The DALI interface allows us to create lighting scenes suitable for various types of activities (presentations, full-concentrated work).

The new lighting system creates a bright, comfortable environment, suitable for educational activities.

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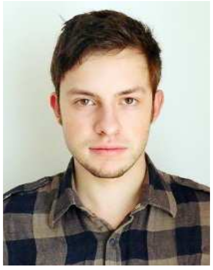

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