

## The Relationship Between Light Distributions and Office Workers' Health: A Pilot Study in Thailand

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*Abstract* - This pilot study investigated the relationship between light distributions in a typical office with side windows and health of workers in Bangkok. Due to the location of photoreceptors ipRGC, which is more dense at the bottom half of the retina, it was hypothesised that there may be a link between the health effects and light intensity and luminance coming from the upper part of a viewer's field of view. Vertical illuminance at the eye level, HDR images of the occupant's field of view and spot luminance were recorded and converted into luminance maps. Thirty-two office workers responded to the self-reported physical and mental health survey (SF-12) as well as the sleep quality (PSQI) and chronotype assessment (MEQ). Statistical analysis suggested a positive relationship between the mental health and the average luminance from the top 25% and top 50% of the field of view measured in the morning. Thus this initial finding highlighted the significance of providing effective daylighting in office buildings.

Index Terms— Keywords: *Circadian rhythms, Light distribution, Health, Mental Health, Mood.*

### INTRODUCTION

The objective of this research is to provide a deeper understanding of the relationship between light and health. The study will include light distribution as a factor affecting people's health in a working environment, adding a new feature for lighting designers which can be useful to design healthier working spaces. To achieve that, we have run our own experiment with light measurements in an office in Thailand with the aim of adding conclusions regarding the effects of light distribution on the subjects' quality of sleep, physical and mental and health. These light measurements are focus on analyzing and comparing lux levels at the cornea level for each participant and the light distribution they are exposed to via luminance maps.

### METHODOLOGY

The current evidence shows higher sensitivity of melatonin suppression when light reaches the lower part of the human retina [1]. Our experiment therefore will go beyond the study of the intensity measure as per illuminance at the cornea level, and will take the whole lit environment into study, with the aim of analyzing the luminance environment for each of the subject in the experiment. The light emitting surfaces is separated into two, with the top part of the luminance map more likely to hit the bottom part of the retina. Statistically, our hypothesis is that the amount of light coming from the top 50% of the subjects' field of view is more strongly correlated to the alignment of our circadian master clock or mood and our health, than the traditional illuminance levels measured at the cornea level.

The chosen scenario of our experiment is an office with traditional fluorescent troffers (2x36W fluorescent recessed luminaires equipped with T8 4000K tubes), and we will analyze several subject's field of view through their luminance map across the day. Questionnaires filled: March 3th 2017. Light measurements taken: March 4th 2017

Data collection: Questionnaires

There are 4 questionnaires for volunteers to fill, each of them will be assessing different information.

- Subject's assessment. This is a 2 pages and 13 questions ad-hoc questionnaire to measure demographic values, eye and sight health, working life and lifestyle. This questionnaire helps us sort the subjects with variables such as: age, body mass index, alcohol intake, lifestyle, sporting activity, working time onset, commuting time, eye sight quality, color blindness, travelling habits, desk seniority...
- PSQI. Pittsburgh Sleep Quality Assessment is a self-report questionnaire that assesses sleep quality over a 1-month time interval. Clinical studies have found the PSQI to be reliable and valid in the assessment of sleep problems and it is considered as the gold standard for self-report questionnaires assessing sleep quality. [2].
- SF-12 The Short Form -12 is the shorter version of the well-known SF-36 questionnaire, a health survey commonly used in health economics as an indicator of the subject's life quality and it has been developed by the non-profit global think tank RAND as a result of the Medical Outcomes Study [3]. This short form of 12 questionnaire and its two components, physical and mental scores have been validated under many health conditions [4]
- The Morningness–Eveningness Questionnaire's main purpose is to measure whether the subjects' circadian rhythm produces peak alertness in the morning, in the evening, or in between. In other words, it assesses the participant's propensity to be an evening or morning person. The MEQ is widely used in psychological and medical research and is correlated with the subjects DLMO [5].

#### Data collection: Light measurements

There are 8 measurements for each of the 32 workstation: illuminance data and luminance maps are obtained at 9:00, 12:00, 15:00 and 18:00, making a total of 256 measurements.

- Illuminance. Luxmeter Minolta previously calibrated and measurements are taken vertically and at 1200mm above the floor at 9:00, 12:00, 15:00 and 18:00.
- Luminance. Nikon D7100 equipped with a fisheye lens fisheye Nikon 10.5 mm 1 2.8 G with non-circular 180° degree field view and aperture range: f/2.8 to f/22. Photographs have been taken in manual mode, with the camera settings as follow: White Balance is 4000K; Sensitivity 100 ISO; Image Size 6000x4000; Aperture size f/2.8; Auto-bracketing 5S +/- 1. In this experiment, exposure variations are achieved with a fixed aperture size f/2.8, and only the shutter speed is varied. This method is more reliable than modifying the aperture size [6]. In order to obtain the luminance maps we use PHOTOSPHERE (Anywhere software), which has been validated as one of the most accurate HDR software currently available. The most predominant feature of PHOTOSPHERE is that accurate luminance values can be obtained by just "picking the pixel value" [7]. In order to assess the direction from where the light is coming, and for simplifying reasons, we look at the luminance mean of the whole field of view, luminance mean of the top 25% part of the field of view and the luminance mean of the top 50% part of the field of view (see figure 1).

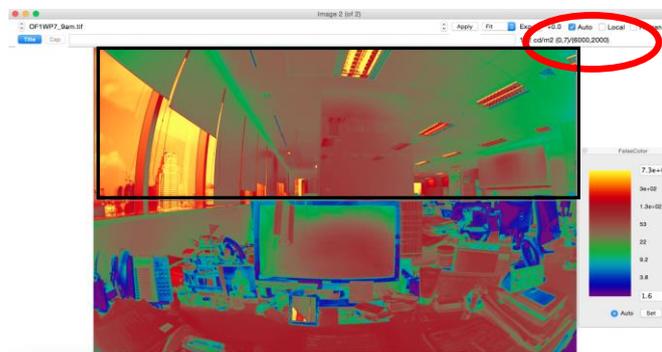


Figure1: Example of the top 50% part of the field of view average luminance value

## RESULTS AND ANALYSIS

32 people, 9 males and 23 females participated. Their age ranged from 26 to 41 years, although there was only one person above 37 years. The mean age was 33 years old with a typical deviation of 3.79. No statically relevant relationship was found between health and lifestyle. Even alcohol and smoking seems not to have a correlation with neither mental, nor physical health for the participants. We may assume that participant's young age is a much stronger factor.

Participants with PQSI score 4 or lesser are considered to enjoy a good quality of sleep, unfortunately only 34.4% of them fell into this category. The mean score is 6.16 with a standard deviation of 2.99. We have also included the chronotype, or the participant's propensity to be an evening or morning person. Results show that 65.6% of them are considered intermediate (not morning or evening person) and only 2 participants (6.3%) fell into a definite category, in this case evening. As far as the overall physical health is concerned, the results from the SF-12 questionnaires show a mean value of 77.41 with 59.4% of the participants obtaining more than 70. Mental health however shows lower results but this might be normal for young people who tend to score greater values at the physical part. Nevertheless its relatively low values might have an underlying reason such as stress for example. The mean value is 65.66 with a standard deviation of 14.65. As of earlier expectation, we found correlation between the three health markers.

A very interesting finding showed a strong correlation (0.545 Pearson's coefficient) between the time to start working and the subjects' quality of sleep. Since both are normal distributions, we conduct ANOVA test, and we found no statistically difference in their variance and the significance level is below 0.05. Therefore there is a difference in terms of quality of sleep between subjects who start working earlier than 08:30 and those later, having a worse sleep quality those start working later. Another interesting finding is that subjects who spent longer time at their desk after 15:00 have worse quality of sleep and mental health. It is unclear whether light intensity of distribution is relevant to this issue.

As far as illuminance values are concerned, we found higher mean values as the day went by, peaking at 15:00 and then dropping at sunset. The reason behind may be direct impact of the sun light in the office due to its orientation. Luminance results are, as expected, in accordance to the illuminance data, with the highest luminance mean across all workstations being at 15:00. See below in table 1 the Luminance mean for the top 50% of the participant's field of view.

<b>Luminance (cd/m2). Top 50% of the field of view</b>				
Time	9am	12pm	3pm	6pm
Mean	850.906	977.156	1.175.906	413.719
Std. Deviation	3.762.675	3.856.364	6.225.654	1.038.797

Table 1: Luminance mean at the top 50% of the subject's field of view

After crossing all lighting measurements with the health markers, we find correlation between mental health and the luminance mean of the top 50% of the field of view. This is quite relevant since correlation was not found between illuminance data and the same mental health marker.

<b>Correlation between Top50% of the Field of View Luminance mean and mental health raw data</b>			
		Top 50% luminance 9am	MCS from SF-12
Top 50% luminance 9am	Pearson Correlation	1	.353*
	Sig. (2-tailed)		.047
	N	32	32
MCS from SF-12	Pearson Correlation	.353*	1
	Sig. (2-tailed)	.047	
	N	32	32

Table 2: Correlation between the top 50% of the field of view and mental health

## CONCLUSIONS AND RECOMMENDATIONS

The result shows a correlation between light from the top part of the subjects' field of view at 9 am and our mental health. Nonetheless we could not find the same correlation between illuminance levels and the same mental health, proving our hypothesis is correct to a certain degree. The mental health component of the SF-12 could be used to detect depressive or mood disorders detector [1]. The International Classification of Diseases is an international standard diagnostic classification produced by the World Health Organization, at its chapter V focuses on "mental and behavioural disorders". Within that chapter of diseases we found the group F3 or mood disorders. Therefore, finding a correlation between light distribution and this SF-12 mental health marker could be somehow expected if we look at both circadian and alertness/mood thresholds. According to most literature light levels triggering effects on our mood/alertness are lower to those influencing both circadian phase shift. Hence, the relatively low light levels present in the office might be the cause behind the lack of correlation between light reaching the bottom part of our retina and physical health or quality of sleep, and could explain why we have found correlation between light coming from the top part of the field of view and mental health interpreted as mood.

The fact that we have found correlation of mental health and light distribution at 9 am shows the importance of light exposure for our mood early in the morning as well, following the normal light therapies practices. Meanwhile, we have found that participants who start working earlier (before 8:30) have a better quality of sleep. This might lead us to think that even if they are exposed to the same intensity and light distribution, they might spend longer time (duration of the exposure) under the office lighting in the morning, and therefore have a positive impact on their sleep quality.

As we have just learned, light coming from the top part of our field of view has a positive impact on our mood and alertness even with the current practices of light levels used in office lighting. This is particularly interesting because with some simply guidelines and without increasing light values, office workers can be mentally healthier. Traditionally, office lighting has been influenced however by global standards or local regulations in terms of efficiency, trying to minimize the energy consumption in the building. Except for the case of natural light integration, the current practices for office lighting design do not really encourage other lighting system than the traditional direct light. Instead, the inclusion of indirect light would not only have an aesthetic effect but also improve our mental health or mood in the long term. The newly coined term "human centric design" goes beyond traditional consideration such as color rendering and power efficiency but instead takes into account other non-visual effects, including our circadian rhythms. This design approach includes intelligent lighting (with sensors and light controls), tunable white and individual light control with the aim of following the specific dynamics of a 24hr light-dark pattern of natural light, activity or task light support and natural light. The benefits of a human centric design approach are being under study. However it does not take light distribution as factor of health lighting design, and as we have shown with the result of our experiment, further research should be needed including light distribution into the equation.

## REFERENCES

- [1] Glickman, G., Hanifin, J., Rollag, M., Wang, J., Cooper, H. and Brainard, G. (2003). Inferior Retinal Light Exposure Is More Effective than Superior Retinal Exposure in Suppressing Melatonin in Humans. *Journal of Biological Rhythms*, 18(1), pp.71-79.
- [2] Buysse, D., Reynolds, C., Monk, T., Berman, S. and Kupfer, D. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research*, 28(2), pp.193-213
- [3] Ware, J., & Sherbourne, C. (1992). The MOS 36-Item Short-Form Health Survey (SF-36). *Medical Care*, 30(6), 473-483. <http://dx.doi.org/10.1097/00005650-199206000-00002>
- [4] Cheak-Zamora, N., Wyrwich, K. and McBride, T. (2009). Reliability and validity of the SF-12v2 in the medical expenditure panel survey. *Quality of Life Research*, 18(6), pp.727-735
- [5] Terman, M., & Terman, J. (2005). Light Therapy for Seasonal and Nonseasonal Depression: Efficacy, Protocol, Safety, and Side Effects. *CNS Spectrums*, 10(08), 647-663. <http://dx.doi.org/10.1017/s1092852900019611>
- [6] Mitsunaga, T. and Nayar, S.K. "Radiometric Self Calibration", *Proceedings of IEEE Conference on Computer Vision and Pattern Recognition*, Fort Collins, June, 1999.
- [7] Bloch, C. *The HDRI Handbook 2.0*. (2013). [S.l.]: Rocky Nook.