A Study of Office Lighting and Indoor Daylight at Leeds

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Abstract

Office is the place where most people works and studies. The lighting conditions in offices are quite important to people who are working or studying in. However, the viewing conditions vary from office to office. The artificial lights used are different, with the types from tungsten to fluorescent. On the other hand, the natural daylight is another significant factor which can vary the indoor lighting. This study held at Leeds aims to find the differences between offices and to generate a standard office lighting and indoor daylight.

Introduction

In industrial practice, many digital images on paper or displays are viewed under office lightings. Although ISO 3664 [1] standardised the viewing conditions for assessing graphic art reproductions, many pass/fail decisions regarding to the reproduction quality are still made under office lightings, which have large variations, i.e. can vary from tungsten to fluorescent lamps such as FL2, FL11 [2]. In colour management systems, it is assumed that they apply CIE illuminant D50. Hence, a CIE technical committee, TC8-10 Research on office lighting for imaging was formed to investigate the spectral power distribution (SPD), illumination level for viewing images in office conditions. Researchers have been encouraged to collect information from their own offices in a worldwide basis. A guideline [3] was produced for all researchers to conduct data collection in a consistent manner.

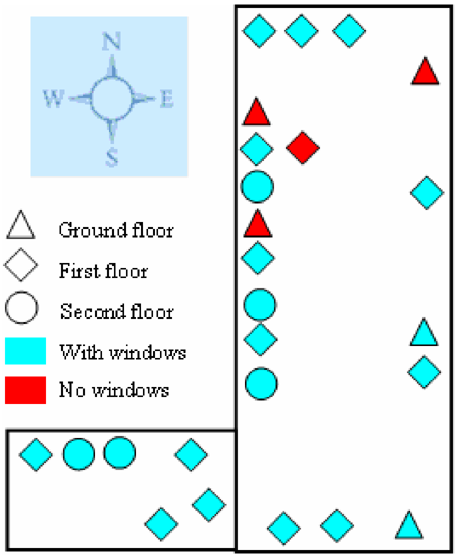
Another issue is the illuminant for assessing the materials containing Optical Brightening Agent (OBA). With the acceptance of CIE outdoor illuminants such as D50, D65, the questions was raised that these illuminants approximate only the SPD of the outdoor daylight, due to the filter effect of window glass, the SPD of daylight in the interior of building differs from this, especially in the UV part of the spectrum. For the proper evaluation of the effect of the materials containing OBA would also need an indoor daylight illuminant. A CIE technical committee, TC1-66 Indoor daylight illuminants was formed. The term of reference is 'to prepare a CIE recommendation on indoor daylight illuminants, considering the needs of the printer international organizations'. A technical report [4] has been written and is in the final ballot stage.

With above in mind, this work was carried out to study the office lighting and indoor daylight at the Department of Colour Science at the University of Leeds.

Experimental

The guideline produced by CIE TC8-10 [3] was closely followed to conduct the current study. Twenty-five rooms in the Department of Colour Science at the University of Leeds were studied. They are located at the Clothworker's Building built in 1874 (see Figure 1a). Figure 1b shows the plane of the building and the position of each room measured. Note that the rooms are located in three different levels, and the walls were painted in nearly white with matt finishing, but slightly in different colours from room to room, i.e. some offices were painted in yellowish white, some in pinkish white.

(a) The Clothworker's Building



(b) The floor plane

Figure 1. The Clothworker's Building and the floor plane of the 25 measured offices in this study

A Minolta CS1000 tele-spectroradiometer (see Figure 2) was used to collect SPD data with wavelength range from 380 to 780 nm and a 1 nm interval. The data was collected during the period of June 2007. The daytime is long and the sunrise was about 4:00 am and sunset was about 20:00 each day.

Three reference papers supplied by the TC8-10 were measured. These were selected to gauge the effects of fluorescence from the different papers. These are: Filter White with no OBA, Alpine White with moderate amount of OBA, and Ultra White has a high amount of OBA. These papers can represent most typical kinds of surfaces people is viewing

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everyday. Three positions were measured in each office: desktop, wall and monitor, which are the typical locations people is viewing in offices. Each office was measured three times in the morning, noon and afternoon, and the time were around 9:00 to 11:00 in the morning; 12:00 to 14:00 at noon and 15:00 to 17:00 in the afternoon. All the above parameters were measured twice with office lights on and off, if it is applicable. The latter represents the indoor daylight. If the room has windows, the window coverings (such as curtains or blinds) were arranged as their typical for the working time period in which the measurements will be taken.

Figure 2. The Minolta CS1000 tele-spectroradiometer, used to measure the office lighting in terms of SPD

Some factors should be considered during the data collection. One is weather condition which will affect the results, for example, in sunny days and in raining days, the indoor lighting environments are quite different. However during the measuring period, it was either overcast or cloudy, so the typical UK weather affect slightly on these results. Another factor is the office itself (the furniture arrangement). Different positions will cause various viewing geometry. It is necessary to choose offices in which furniture have been arranged in different ways.

The data analysis was carried out by simulating to view a GretagMacbeth ColorChecker DC chart (see Figure 3). It was specifically designed to meet the needs of digital photography by giving a good coverage of colour space including 240 colours. The data analysis was conducted with the following procedure:-

1. To calculate the XYZ values of each colour in the DC chart by multiplying the SPD of a reference white paper under the lighting of interested, the CIE 1964 standard colorimetric observer and the reflectance of the colour considered. The reference paper was set as the illuminant.

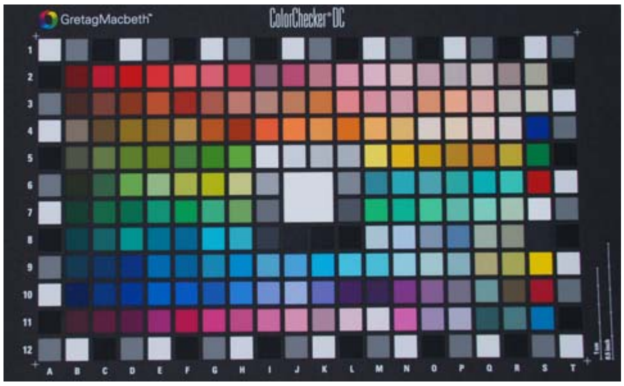

Figure 3. The GretagMacbeth ColorChecker DC chart

2. When comparing two conditions in each room say two locations, the CIEDE2000 [5] colour difference was calculated. The mean and maximum colour differences were then recorded to represent the discrepancy between the two conditions studied.
3. Finally, the mean and maximum differences were averaged to represent the overall trend. The measure is known as MCDM, mean from a set of mean colour differences.

Results

The results in terms of MCDM in CIEDE2000 colour difference (ΔE_{00}) to compare three different locations (desktop, wall and monitor) in a room, three different papers (filter, alpine and ultra white paper) and three time periods (morning, noon and afternoon) of measurement are summarised in Table 1.

The results in Table 1 showed that for office lighting, the largest variation is due to location in the room, followed by paper difference and time difference. The impact due to paper and time period is similar. This implies that critical print assessments should be always performed in a fixed location in an office. For indoor daylight, the largest variation is still caused by location difference; however, paper difference has a larger impact than time difference. This means that OBA contents in paper substrates do have an impact of colour appearance.

Table 1 Summary of the mean and maximum differences between different parameters studied

	Office Lighting				Indoor Daylight			
Location difference	DM	DW	MW	Mean	DM	DW	MW	Mean
Mean	2.98	3.34	3.65	3.32	2.93	3.51	3.77	3.40
Maximum	10.91	11.83	12.95	11.90	10.67	12.71	13.87	12.42
Paper difference	FA	FU	AU	Mean	FA	FU	AU	Mean
Mean	1.75	2.50	0.83	1.70	2.38	3.43	1.22	2.34
Maximum	5.70	8.07	3.34	5.71	7.53	10.77	5.15	7.82
Time difference	MN	AM	AN	Mean	MN	AM	AN	Mean
Mean	1.47	1.87	1.54	1.54	1.45	1.79	1.20	1.48
Maximum	6.12	7.40	6.52	6.52	5.50	7.23	4.78	5.84

Note: Three locations: desktop (D), wall (W) and monitor (M), i.e. DM means the location difference between desktop and monitor;
Three papers: Filter (F), Alpine (A) and Ultra (U) white paper, i.e. FA means the paper difference between filter and alpine papers;
Three time periods: morning (M), noon (N) and afternoon (A), i.e. MN means the time difference between morning and noon.

Table 2 The variations and colour specifications of three light sources in this study.

	MCDM (ΔE_{00})		Colour Specifications				
	MAX	MEAN	Luminance (cd/m2)	CRI	CCT (K)	x	y
FL11 (9*)	11.98	4.66	174	88	4383	0.3662	0.3727
FL02 (16*)	13.73	4.36	201	75	4203	0.3729	0.3754
Indoor Daylight (19*)	8.89	2.64	143	99	5400	0.3348	0.3465

★The numbers in the brackets are the number of offices studied, i.e. there are 9 and 16 offices illuminated with FL11 and FL02 light sources respectively. The indoor daylight was measured from 19 offices, and the rest 6 offices were either illuminated with sensor-controlled lamps or specially built without window.

Table 3 The MCDM values between CIE D65, D50, ID65, ID50 and Indoor daylight of this study

MCDM (ΔE_{00})	Maximum	Mean
CIE D65	8.58	4.38
CIE D50	6.78	3.06
Proposed ID65	10.03	4.81
Proposed ID50	7.44	3.44

Properties of Office Lighting and Indoor Daylight Studied

Spectral Power Distributions and Colour Specifications

There are two types of light sources used in the building studied: FL11 and FL02. The SPDs of an office measured from different locations (desktop, wall and monitor), different papers (filter, alpine and ultra white paper), and different time (morning, noon and afternoon) were normalised and averaged to represent the typical office lighting. The SPD for the combined FL11, FL02 office light and indoor daylight are plotted in Figure 4 and the specifications including the average luminance, colour rendering index (CRI), correlated colour temperature (CCT) and chromaticity coordinates (x, y) of three light sources are listed in Table 2.

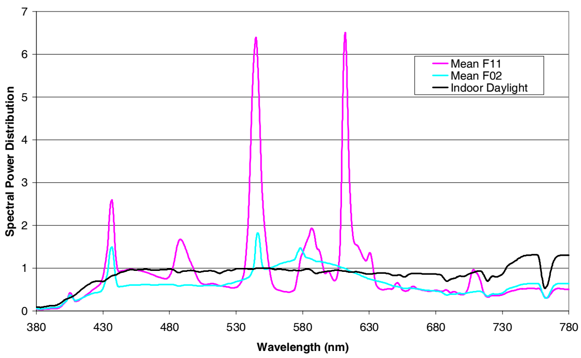

Figure 4. The SPD for the combined FL11, FL02 office lights and indoor daylight

Comparing with CIE illuminants

The indoor daylight obtained from this study was compared with CIE D65, D50, and the indoor daylight proposed by TC1-66 (designated as ID65 and ID50). The results in terms of MCDM tested using the DC chart are given in Table 3. The results from Table 3 showed that the indoor daylight at Leeds is close to CIE D50 and ID50 illuminants.

Conclusions

This study investigates the typical office lighting and indoor daylight of the Department of Colour Science at the University of Leeds. The results showed a large variation between office lightings in different rooms. The indoor daylight is reasonably close to D50 and the TC1-66 proposed ID50.

References

[1] ISO 3664:2000, Viewing conditions – graphic technology and photography.

[2] CIE. Colorimetry 3rd Edition. CIE Publ. 15: 2004, Central Bureau of the CIE, Vienna, Austria, 2004.

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[4] CIE TC1-66 draft report.

[5] M. R. Luo, G. Cui and B. Rigg, "The Development of the CIE 2000 Colour-Difference Formula: CIEDE2000," Color research and application, 26, 340 (2001).

Author Biography

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