An evaluation of the lighting environment in the public space of shopping centres

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Abstract: Interior lighting quality influences people's visual comfort and satisfaction with a space. Based on a field study about the effects of lighting environments on occupancies in eight shopping malls with three different latitudes and a wide range of size from 30,000 to 210,000 m^2 all over China, this study investigates the differences in subjective evaluations, the correlations between the lighting environments of public spaces and people's evaluations, and the regressions of scene mean luminance. A questionnaire survey and HDR-image techniques have been used to gather subjective feedback and collect physical lighting data. The results show that the subjective evaluations among different groups (gender, age, education background, and duration of stay in the shopping malls) are similar. The existence of daylighting plays an important role in subjective satisfaction, but not crucial enough to their brightness perception. The mean luminance values of these scenes are closely correlated to the diversity of the subjective evaluations. For shopping centres, the optimal L_{mean} value is 1000 cd/m^2 for a mixed daylighting and artificial lighting environment, and 75 cd/m^2 as the recommended L_{mean} value for an artificial lighting environment.

Keywords: Shopping centre; Public space; Light environment; Luminance metric; Subjective evaluation

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1. Introduction

The turnover effects of shopping centre environments such as value perception, satisfaction, loyalty, and behaviours like the length of stay and shopping have been studied from the viewpoint of psychology [1-5]. The quality of light environment is an important consideration in shopping centres. Improving the artificial lighting and introducing daylight has positive effects on turnover [6-9].

In terms of evaluating the light environment, the results of differential analysis may vary in different types of buildings. In the office, there is no significant difference amongst age groups regarding visual satisfaction [10]; The satisfaction with lighting of those workers occupying stations closer to the windows was significantly higher than those located in the core areas; However, gender elicited a difference in the evaluation of satisfaction with lighting only in the core areas and men's ratings were higher than the women's [11]; Significant gender differences were observed for mean satisfaction level with each indoor environmental quality factor based on data from office buildings [12]; User satisfaction revealed significant differences in illuminance level in different workstation locations in modern offices located in Southern California[13]. In Hong Kong housing units, no significant difference was found between males and females, however, distinct differences were found amongst age groups in satisfaction evaluation, and the elders' ratings were the highest [14]. Using nonparametric statistics, the differences among schools and between genders were studied based on physical measurements and a questionnaire survey in 28 classrooms in seven Italian primary schools [15]. The majority of differential analysis conducted on the shopping centre is about consumption psychology and behaviour [16, 17], but the field of light environment evaluation is studied less. Space layout is related to spatial attributes and various types of merchandise, which are related to the characteristics of the users in the shopping centre. It is therefore essential to study the differences in light environment evaluation according to the types of light and the characteristics of occupants.

Although average illuminance is the most widely used metric in lighting design and standards, luminance is more suitable for the study of acceptance and preference in light environments than illuminance [18]. Luminance is a metric which combines light energy in the visible region with the spectral sensitivity of the human visual system [19]. Luminance is widely applied for many measures of direct visual stimulation and performance [20]. Earlier research on the relationship between luminance level and subjective evaluation was focused on object and background luminance [21, 22], but it is difficult to get scene luminance values. In recent years, with the development of high dynamic range (HDR) imaging techniques, it is possible to collect luminance data of whole scenes [23]. It has also been proven that the error margin is less than 10% by comparing HDR images and the actual measurements, which indicates that the per-pixel luminance value has reasonable accuracy and repeatability [24]. HDR imaging techniques can take into account all the luminance information in the view and the appropriate luminance metric to explain variability in subjective responses has been gradually explored. In the office located in Boise, Idaho, the most effective metrics are mean luminance of the task, and mean luminance of the entire scene; In terms of satisfaction with the view, standard deviation of the entire scene luminance is also a good predictor [25]. The predictive ability of the luminance-based metric for each questionnaire item is explored using HDR images and subjective evaluations from four separate field sites during winter 2016 in Eugene, Oregon [26]. The viability of HDR image tool is demonstrated, highlighting reduced luminance contrast on the egress staircase for lower visual acuity conditions [27]. There have been many developments in the field of luminance uniformity, daylight glare evaluation and sky modeling by using HDR imaging techniques [25, 28-38]. HDR imaging techniques are a more suitable method to evaluate light environment in shopping centres that have no fixed task position, however, the research in this field is scarce. In order to explore the appropriate metrics applied to the public spaces in shopping centres, luminance-based metrics including luminance level, luminance distribution, and the ratio of luminance are measured by using HDR images.

There was a statistically significant relationship between impressions and lighting levels [39]. The regression of light environment evaluations and objective metrics can provide evidence for design indexes and index classification. In the office, the relationship between the proportions of the respondents who selected ‘satisfaction’ and illuminance is in the normal distribution, and a value of 2000lx corresponds to the ‘most satisfactory’ level which is taken as a basic reference by CIE standard; In the traffic space, the subjective evaluation has the closest relationship with average cylindrical illuminance, and a value of 100lx corresponds to ‘very good’ which is taken as a standard value in a similarity space [40]. Brightness level is set according to luminance of the target and background [22]. The illuminance values in similarity spaces were usually proposed through research in a simple space, but the method is limited to meeting the basic demands of visual function and ignores the effects of building types on environmental psychology. In recent years, regression models for predicting the relationship between brightness and illuminance have been more common for office and education buildings [41-44], however, we found only one study on large commercial buildings [45]. Since there is no research on the relationship between scene luminance-based metrics and subjective responses, this study therefore concentrates on it.

The aim of this paper is to explore the general satisfaction with light environments and occupants' perceptions of luminance through a field study including both objective measurements and questionnaire surveys in shopping centres. We considered three aspects: we examined the differences caused by the characteristics of the users and two forms of lighting in subjective evaluations; we analysed the correlations between scene luminance-based metrics (absolute value, the percentage of the rating level, and luminous distribution) and subjective responses in order to determine the most effective metric; and we constructed the functions of subjective evaluation towards the lighting environment.

2. Methodology

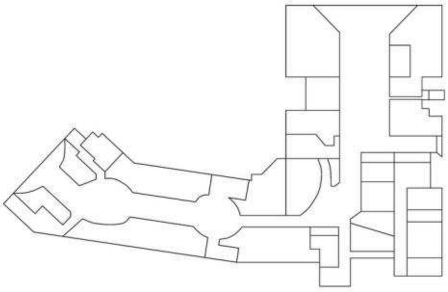
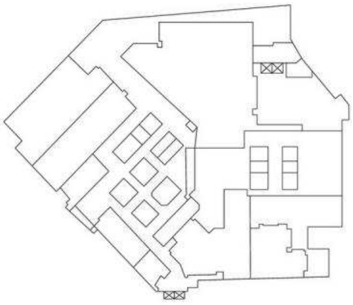
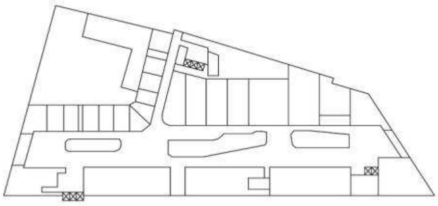
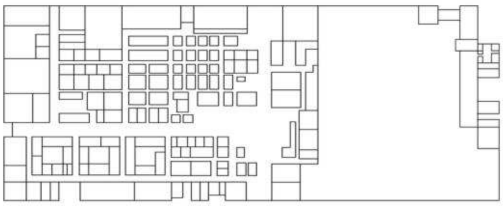
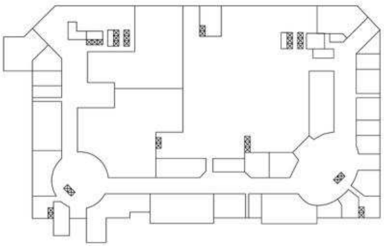
2.1. Sites

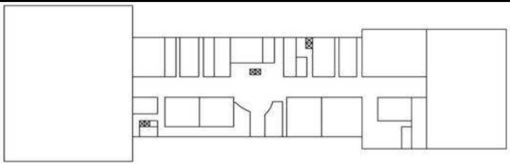
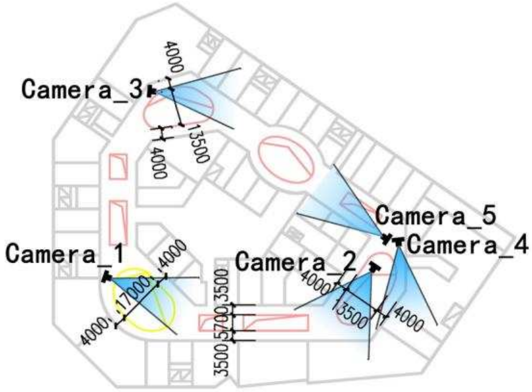
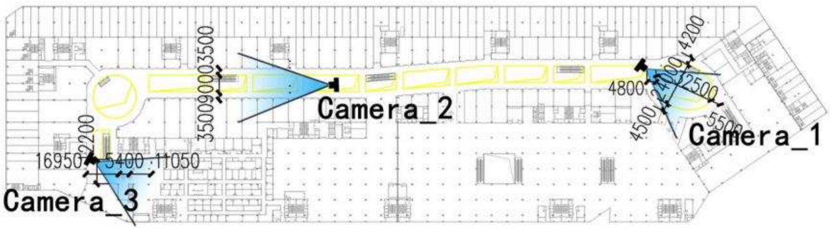
The pedestrian street and atrium are the two most important types of public space in shopping centres. Their functions include business, traffic organization, and landscape. Consumers may remain in them for a longer period to go shopping, have a rest, or play, therefore, we chose these two public spaces for the field survey.

We selected eight shopping centres from four cities in China, namely Shanghai (NL31°), Nanjing (NL31°), Langfang (NL35°) and Harbin (NL45°). There are variations in climate, economic level, and cultural characteristics in these four sites. Table 1 shows the area and floor plans of the shopping centres, the locations, and the number of the participants in each site accordingly. The eight case studies differ in size (small, medium, large, and super large). We studied two typical forms of lighting: only artificial lighting and mixed lighting with daylight. There are two main types of daylight in the public space of shopping centres—one type is skylight (No.1, No.3, No.4, No.5, No.6, No.7, No.8), and the other type is sidelight (No.1, No.2, No.6). The skylit space was selected for a more detailed study and this also avoided the orientation effect.

Table 1

Basic information of the case study sites. (For interpretation of the reference to colour in this table, the reader is referred to the web version of this article.)

No.	City	Size (m^2)	Floor plan	Number of interviews
1	Shanghai	67.000		31
2	Nanjing	60.000		10
3	Nanjing	160.000		10
4	Langfang	80.000		37
5	Langfang	88.000		36

6	Harbin	30.000		50
7	Harbin	123.870		47(41)
8	Harbin	210.100		60(57)

We carried out a more detailed study in two shopping centres, namely No.7 and No.8. The yellow and red lines stand for opening with and without daylight respectively, as shown in Table 1. One atrium has daylight in building No.7, while others have not. All of the pedestrian streets and the atriums have daylight in building No.8. Seventeen scenes in total were selected in the detailed study. The number of scenes with only artificial lighting is seven, on Floor 1 (Camera_2 and Camera_3), Floor 2 (Camera_4 and Camera_5), Floor 3 (Camera_5) and Floor 4 (Camera_4 and Camera_5) in building No.7. The number of scenes with daylight and artificial lighting is ten, on Floor 1 (Camera_1), Floor 2 (Camera_1) and Floor 3 (Camera_1) in building No.7, and on Floor 1 (Camera_1 and Camera_2), Floor 2 (Camera_1 and Camera_2) and Floor 3 (Camera_1, Camera_2 and Camera_3) in building No.8.

2.2. Questionnaire survey

Table 2 shows a summary of the previous studies in the field of lighting evaluation. The maximum and minimum number of interviews are 614 and 60. The sample sizes are mostly between 100 and 350. In this research, a research plan in accordance with the previous studies was made. For each site 30–60 interviews were carried out. In total 281 interviews were conducted in eight public spaces in shopping centres, of which 98 interviews were part of a more detailed study in two shopping centres. The interviewees were selected randomly.

Table 2

Summary of the research in the field of lighting evaluation.

Research area	Source	The type of building	The locations of studies	Number of interviews	Contents
Differences	Boyce, 1973[10]	Laboratory	-	150	Age groups
	Boubekri, 1995[11]	Office	-	102	Characteristics of user and the lighting conditions
	Xue et al. 2014[14]	Residence	Hong Kong, China	340	Characteristics of users
	Giuli V D et al. 2012[15]	Classroom	Ceggia, Noventa di Piave, Maerne, Spinea, Italian	614	Among schools and between genders
Effective metrics	Reinhart et al. 2012, 2014 [46, 47]	Classroom	-	60/334	Daylight availability metrics
	Van Den Wymelenberg et al. 2010 [25]	Office	Boise, Idaho	150	Predicting human visual comfort
	Konis, 2014 [30]	Office	San Francisco, California	523	
	Mahić A et al. 2016 [26]	Classroom and meeting room, conference room, atrium	Eugene, Oregon	149	

		and study area, classroom			
Relationship between subjective evaluation and objective metrics	Mui and Wong, 2006 [41]	Office	Hong Kong, China	120	Average illuminance and lighting satisfaction
	Cao et al. 2012 [42]	Office, library, classroom	Beijing and Shanghai, China	500	
	Huang et al. 2012 [44]	Office	Beijing, China	293	
	Jin and Li, 2014 [45]	Commercial building	Harbin, China	459	Horizontal illuminance and brightness

The space layout is based on the commodity classification which is related to the gender and age of the consumer. The evaluation of environment may differ among consumers with different education levels and lengths of stay which might cause a change of physical strength and mood. Therefore, interviewees were asked to record gender, educational background, age, and length of stay in the shopping centre.

The semantic differential method is widely used in the subjective evaluation towards the physical environment [48-51]. A subjective evaluation of light environment was also carried out, including satisfaction (five scales were used: 1, very dissatisfied; 2, dissatisfied; 3, neutral; 4, satisfied; and 5, very satisfied) and the luminous level (seven scales were used: 1, too dim; 2, dim; 3, dimmer; 4, neutral; 5, brighter; 6, bright; and 7, too bright).

The effect of natural and artificial lighting has been studied, and it has been shown that the evaluations of spaces with daylight are generally positive [52-55]. Therefore, the lighting conditions have been recorded in the case studies.

2.3. Objective data from HDR images

In the seventh and eighth buildings, we photographed multiple images while the questionnaires were distributed to participants. The Nikon D60 camera was used to take a sequence of images at f/5.6 at varying shutter speeds to cover a range from low to high brightness. Three points from a grey card were measured by a XYL-Ⅲ luminance meter with each scene for the calibration of the HDR images.

The HDR images were combined and analysed in Aftab alpha software. Figure. 1 shows two examples of the luminance distribution gathered from the atriums of two shopping centres. Compared with the first atrium, the access of daylight in the second atrium provides a dynamic lighting environment with a wider luminance distribution that mainly ranges from about 0cd/m^2 to 3000 cd/m^2. The luminance data extracted from these HDR images are the mean luminance value of a scene (L_{mean}), the maximum (L_{max}) and minimum (L_{min}) luminance value, and the median luminance ratio of a scene (L_{median}). The appearance of ambient illumination that is related to adaptation levels and eye illuminance is divided into five scales [56]. This study selected two limits, 30cd/m^2 corresponding to 'lowest level for acceptably bright appearance' and 300cd/m^2 corresponding to 'distinctly bright appearance' as the metric. Therefore, the percent of luminance ratios below 30cd/m^2 (L_{30}) and the percent of luminance ratios above 300cd/m^2 (L_{300}) were also calculated. Furthermore, the fluctuation of luminance distribution (L_{std}, which is the standard deviation of luminance values), luminance contrast ($L_{max/min}$, which is the ratio between the maximum and minimum luminance ratios of a scene), and luminance uniformity ($L_{min/mean}$, which is the ratio between the minimum and mean luminance ratios of a scene) were also used for HDR images analysis.

Fig. 1. The HDR images and falsecolor images of two atriums in the shopping centres. (a)An atrium without daylight; (b) An atrium with daylight.

3. Results

3.1. Differences in lighting evaluation

The effects of the users' characteristics and the lighting conditions on satisfaction and brightness of lighting environment, which are based on nonparametric tests of independent samples, are discussed in this section. The Mann-Whitney U test and Kruskal-Wallis-test were used to evaluate 2-independent and k-independent samples respectively.

3.1.1. The characteristics of the users

Table 3 shows the differences in subjective lighting evaluation among the various groups by gender, education level, age, and the length of stay for 281 interviews in all. In terms of occupant satisfaction and brightness, there is no significant difference among different population groups ($p > 0.05$). Therefore, the classification of interviewers was not taken into account. The results of this study show some differences from previous research in other types of buildings. Some studies about office buildings show that there is no significant difference amongst various age groups, and significant difference is found between different genders in core office areas, but not from those closer to the windows [10, 11]. A study in Hong Kong housing units showed that there is significant difference amongst various age groups, but not between males and females [14].

Table 3

The differences among different population groups.

		Number of interviewees	Satisfaction（1-5）		Brightness（1-7）	
			Mean	Significance	Mean	Significance
Gender	Male	121	3.52	0.230	3.98	0.083
	Female	160	3.58		4.14	
Education level	High school and secondary school	67	3.69	0.260	4.25	0.421
	Bachelor degree	142	3.43		3.98	
	Master degree or above	72	3.41		4.06	
Age	≤28	132	3.52	0.914	4.03	0.633

	29-40	78	3.50		4.00	
	⩾41	71	3.52		4.11	
The length of stay	Within an hour	85	3.43	0.402	4.04	0.561
	1-2 h	99	3.45		4.04	
	2-3 h	58	3.61		4.02	
	More than 3 h	39	3.51		4.23	

3.1.2. The lighting conditions

We conducted a difference analysis between the two lighting conditions. The number of interviewees is 177 and 104 respectively with and without daylight. Whether there was natural lighting in the space had a significant effect on occupant satisfaction ($p < 0.05$). The mean scores in the conditions with and without daylight are 3.62 and 3.40 respectively. The result corresponds well with previous studies which demonstrate that people show positive attitudes towards daylighting evaluations. Nearly 78% of students thought working under daylighting conditions were better than under artificial lighting [53]. In libraries, occupants preferred the zones closer to the window [55]. In offices, whether users were situated close to the windows or not had a significant effect on lighting satisfaction [11]. Our study shows no significant effect on the brightness whether there is daylight or not ($p > 0.05$). Therefore, the data of the two different lighting conditions was analysed separately in the evaluation of satisfaction, but those were regarded as a whole to study in the evaluation of brightness.

3.2. The correlation between subjective evaluation and luminance-based metrics

In order to check the correlation between subjective evaluation and luminance-based metrics, we used Pearson's chi-square test in the two case study sites. The influence of data dimension was eliminated by taking the base-10 logarithm of luminance values (mean value, absolute max. value, absolute min. value, median value and standard deviation of scene luminance). The initial data was converted into undimensioned data, and the values of subjective evaluation and objective index could then be compared at the same level.

3.2.1. The satisfaction under natural and artificial lighting conditions

The correlations between lighting satisfaction and luminance-based metrics under natural and artificial lighting conditions, based on data from a 61 occupant-survey, are shown in Table 4. There are strong correlations between L_{mean} , L_{max} ,L_{min}, L_{median}, L_{std}, L_{30}, L_{300} and the mean lighting satisfaction evaluations ($p<0.01$). The correlation with L_{30} is negative, whereas the other metrics are positive. There is a good correlation between luminance uniformity ($L_{min/mean}$) and the mean lighting satisfaction evaluation ($p<0.05$). There is no correlation between luminance contrast ($L_{max/min}$) and the mean lighting satisfaction evaluation ($p>0.05$). Based on the significant level, the first available metric to evaluate the lighting satisfaction of the scene is L_{mean}, followed by L_{std} and L_{30} under the mixed lighting conditions.

Table 4

Pearson correlation coefficients between the satisfaction of lighting environment and luminance-bases metrics in the spaces with daylight and artificial lighting.

	Lg (initial data)					Initial data			
	L_{mean}	L_{max}	L_{min}	L_{median}	L_{std}	$L_{max/min}$	$L_{min/mean}$	L_{30}	L_{300}
Correlation	0.874**	0.775**	0.790**	0.812**	0.858**	0.507	-0.663*	-0.845**	0.799**
Significance	0.001	0.008	0.007	0.004	0.002	0.135	0.037	0.002	0.006

**$p<0.01$.

* $p<0.05$.

3.2.2. The satisfaction under only artificial lighting conditions

Table 5 demonstrates the correlation between lighting satisfaction and luminance-based metrics under artificial lighting conditions based on the use of the survey data collected from 37 individuals. There is a good positive correlation between L_{mean} and the mean lighting satisfaction evaluation ($p<0.05$), whereas others metrics are not related to that.

Table 5

Pearson correlation coefficients between the satisfaction of lighting environment and luminance-bases metrics in the spaces only with artificial lighting.

	Lg (initial data)	Initial data

	L_{mean}	L_{max}	L_{min}	L_{median}	L_{std}	$L_{max/min}$	$L_{min/mean}$	L_{30}	L_{300}
Correlation	0.831*	0.342	-0.064	0.712	0.637	0.156	-0.331	-0.658	0.096
Significance	0.021	0.453	0.892	0.073	0.124	0.738	0.468	0.108	0.838

*$p < 0.05$.

The above results are different from the ones from previous studies conducted in offices. A study on exploring the effective metrics to explain variability in subjective satisfaction responses shows that the top ten metrics are Max L Scene, Standard Deviation of Scene L, Mean L Glare Sources (based on five different mean luminance thresholds), DGP 10* Median L Scene, Mean Task L, and Sum Solid Angle of Glare Sources [25].

3.2.3. The brightness evaluation of the luminance level

Table 6 shows the correlations between the brightness evaluation and luminance-based metrics based on the use of the survey data collected from 98 individuals. There are strong positive correlations between the mean brightness evaluations and the metrics of L_{mean} , L_{max} , L_{std} and L_{300} ($p < 0.01$). There are good positive correlations between the mean brightness evaluations and the metrics of L_{median} and $L_{max/min}$ ($p < 0.05$). There is no correlation between the mean brightness evaluations and the metrics of L_{min}, $L_{min/mean}$ and L_{30}. Based on the significance level, the first available metric to evaluate the brightness of the scene is L_{max} , the second is L_{std}, the third are L_{mean} and L_{300}.

Table 6

Pearson correlation coefficients between the brightness of lighting environment and luminance-bases metrics.

	Lg (initial data)					Initial data			
	L_{mean}	L_{max}	L_{min}	L_{median}	L_{std}	$L_{max/min}$	$L_{min/mean}$	L_{30}	L_{300}
Correlation	0.629**	0.678**	0.409	0.597*	0.661**	0.527*	-0.448	-0.465	0.625**
Significance	0.007	0.003	0.104	0.011	0.004	0.030	0.071	0.060	0.007

**$p < 0.01$.

*$p < 0.05$.

The correlation analysis in Table 4-6 shows that the scenes' mean luminance value is significantly related to an individual's satisfaction degree and brightness perception, hence L_{mean} is proposed as the predictor to evaluate occupants' estimation of lighting environments in shopping malls.

3.3. The regression of lighting evaluation

The relationships are established between the scenes' mean luminance and the subjective evaluations. Each symbol of the regression curves represents the average of the subjective evaluations at the same scene. The range of the scenes' mean luminance is from about 28 cd/m^2 to 1120 cd/m^2 in this study.

3.3.1. The satisfaction under natural and artificial lighting conditions

Figure 2 shows the relationships between L_{mean} and subjective satisfaction under natural and artificial lighting conditions using the survey data collected from 61 individuals, with a binomial regression and the R^2 is 0.7944. When the L_{mean} is lower than a certain value, say 500 cd/m^2, there is a remarkable growth in lighting satisfaction evaluation with the increase of the L_{mean}, whereas at the growth becomes progressively slower if the L_{mean} continues to increase. The evaluation value shows a peak when the L_{mean} is 1000 cd/m^2.

3.3.2. The satisfaction only under artificial lighting conditions

Figure 3 shows the relationship between L_{mean} and subjective satisfaction under artificial lighting conditions using the survey data collected from 37 individuals, with a linear regression and the R^2 is 0.7425. When the L_{mean} values are 37cd/m^2 and 75 cd/m^2, the average evaluation scores are about 3 (neutral) and 4 (satisfied) respectively. By considering the evaluation values, we see that the recommended value is 75 cd/m^2 for satisfaction under artificial lighting conditions.

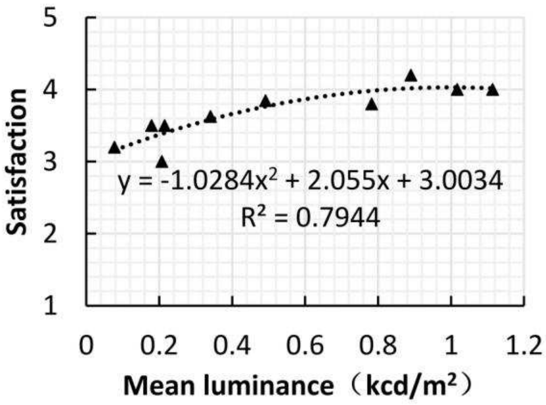


Fig. 2. The relationship between satisfaction and mean luminance under natural and artificial lighting conditions.

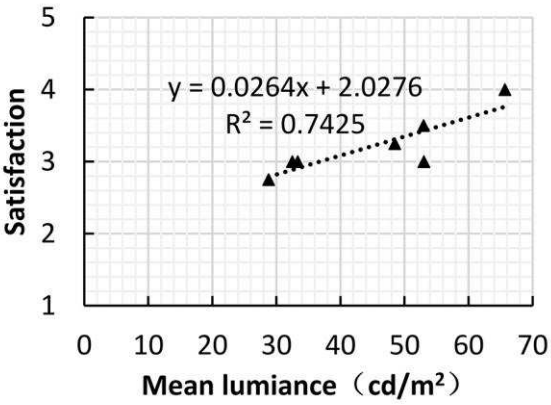


Fig. 3. The relationship between satisfaction and mean luminance under only artificial lighting conditions.

In previous studies, the regressions of the lighting satisfaction evaluations are mainly based upon horizontal illuminance and carried out in offices (Hong Kong and Beijing), libraries (Beijing and Shanghai) and classrooms (Beijing and Shanghai). When the horizontal illuminance level is 1000lux, the satisfaction value is the highest [41-44, 57]. In order to compare with previous results, we converted our scene mean luminance values into eye vertical illuminance (E_Veye), according to E_Veye≈3.3* L_{mean} [56, 58]. That is to say, the peak E_Veye value is 3300 lux under mixed lighting conditions; The recommended E_Veye value is 248 lux under artificial lighting conditions.

3.3.3. The brightness evaluation of the luminance level

Figure 4 shows the relationship between L_{mean} and the brightness evaluation using the survey data collected from 98 individuals with a logarithm regression. The predictive equation passed the F test ($p < 0.05$). There is a significant correlation between the two, however the R^2 is rather low at only 0.3951. When the L_{mean} level is 200 cd/m^2, the average evaluation score is about 4 (neutral). In addition, the brightness is found to increase quickly with increasing L_{mean} level when it is lower than 200 cd/m^2, whereas the brightness is approximately constant when L_{mean} is higher than 200 cd/m^2. The corresponding brightness values are 3.5 and 4.5 respectively, when L_{mean} is 24 cd/m^2 and 1720 cd/m^2.

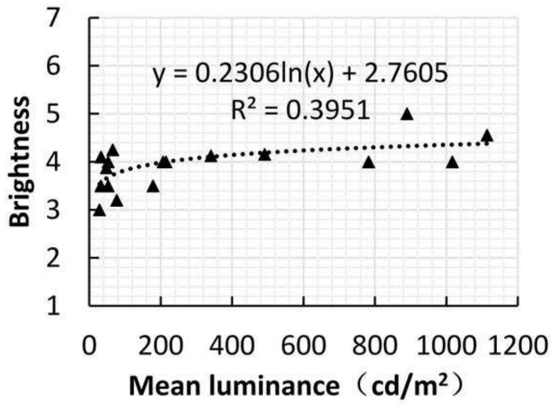


Fig. 4. The relationship between brightness and mean luminance.

We compared our scene brightness evaluations to Bodman et al's research on the surface brightness of objects. The regression of the scene brightness evaluation is similar to previous results of Bodman's research. However, the range of the brightness values is not wide in our study, a possible reason being that the brightness is based on the whole scene perception of users and is ranged from 1 to 7, whereas Bodman's research is based on the relative brightness amongst all the objects which is ranged from 1 to 100. The findings by Bodman et al are as follows: the relationship between brightness and object luminance is an S-shaped curve; under artificial lighting conditions, the scope of curve is the largest when the luminance ranges from 1cd/m^2 to 100 cd/m^2, and the brightness values at 100 remain unchanged when the luminance level is above 500 cd/m^2; under daylighting conditions, the scope of curve is the largest when the luminance ranges from 5 cd/m^2 to 200 cd/m^2, and the brightness values at 95 remain unchanged when the luminance level is above 1000 cd/m^2[59].

4. Conclusions

Based on occupants' evaluation and the luminance maps generated through the HDR-image techniques in eight shopping centres, we propose the conclusions below:

1) On the whole, there is no difference in responses based on the characteristics of users. In addition, the effects of daylight in a space on subjective evaluation have been studied. The existence of natural lighting in shopping malls can increase an individual's satisfaction with the lighting environment, which is consistent with previous research. However, natural lighting fails to impact individuals' brightness evaluation.

2) Based on this field study, the following luminance-based metrics for commercial environments are proposed: the three most effective metrics to reveal the participants' evaluation are L_{mean}, L_{std}, and L_{30} in the mixed daylighting and artificial lighting conditions. L_{mean} is the only metric that has a significant correlation with the satisfaction evaluation in the artificial lighting only environments. For brightness evaluation, the top effective four metrics are L_{max}, L_{std}, L_{mean}, and L_{300}. In conclusion, there is a significant correlation between subjective evaluation and the mean luminance value of a scene. Therefore, the mean luminance value of a scene is proposed as an appropriate metric to estimate users' responses to lighting environments in the public spaces of shopping centres.

3) According to the regression between subjective evaluation and the mean luminance value of a scene, 1000 cd/m^2 is recommended as the mean luminance value with the existence of both natural and artificial lighting; 75 cd/m^2 is recommended as the mean luminance value in only artificial lighting conditions. Furthermore, 200 cd/m^2 provides the occupants with a neutral perception of brightness. The interviewers felt that the light environment become 'darker' and 'brighter' respectively, when L_{mean} values become 24 cd/m^2 and 1720 cd/m^2.

Furthermore, it is noted that the overall comfort should be taken into account including soundscape and smellscape, for example, where considerable works have been carried out [60-62].

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