7th International Building Physics Conference

IBPC2018

Proceedings
SYRACUSE, NY, USA
September 23 - 26, 2018

Healthy, Intelligent and Resilient
Buildings and Urban Environments
ibpc2018.org │ #ibpc2018

The impact of physical environments in satisfaction in shopping centers

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ABSTRACT

Lighting, thermal and acoustic are three main components of indoor physical environments affecting people's satisfaction, productivity and health. Good physical environments in shopping centers not only improve the environment atmosphere but also increase the customers' satisfaction. This study aims to find correlations between the physical environments and the satisfaction levels. Firstly, an objective measurement of physical environments had been carried out in four shopping centers. Then, a subjective evaluation was carried out in a real scene laboratory by changing four kinds of illuminance and three types of Correlated Color Temperatures (CCTs), which aims to find the relationship between the lighting environment and people's lighting, thermal and acoustic satisfaction. Moreover, the interaction of satisfaction levels were also explored. The results of field study showed that lighting and acoustic environments have a wide fluctuate range in four shopping centers. The experiment found that illuminance has a significant effect on lighting satisfaction and is best at 1000 lux (lx). The thermal and acoustic satisfaction were not directly influenced by lighting parameters; however, they had the interactions with lighting satisfaction, which showed that lighting environment would enhance the satisfaction levels of thermal and acoustic environments when it was satisfied.

KEYWORDS
Shopping centers; Physical environments; Satisfaction level; Interaction

INTRODUCTION
With the improvement of people's demand for shopping, indoor environment quality (IEQ) is more and more important for shopping centers. As a part of the indoor environment, physical environments- lighting, thermal and acoustic- greatly affect consumers' satisfaction levels (Zhao et al. 2015; Jin et al. 2017).

For satisfaction evaluations, several studies have attempted to find the relationship among lighting, thermal and acoustic environments. Huebner et al. (2016) confirmed that CCT can affect people's thermal comfort. Ma and Nie (2014) found improving lighting environment quality reduced the noise annoyance and increased the acoustic comfort. Geng et al. (2017) indicated that when the thermal environment was satisfying, it raised the "comfort expectation" of lighting and acoustic factors. Above studies showed that physical environments will strengthen or weaken each other. However, most of the studies focused on residential, office, campus buildings, etc. (Ma and Nie, 2014; Geng et al. 2017; Ricciardi and Buratti, 2017), and seldom refers to shopping centers. Therefore, it's necessary to explore the physical environment satisfaction for shopping centers.

As for the research method, field study is frequently used in shopping centers (Zhao et al. 2015; Jin et al. 2017). Through field study, physical environments can be measured accurately, however, satisfaction levels of customers are usually influenced by many nonphysical factors like spatial and social parameters (Meng et al. 2013), which influenced

the accuracy of physical environment evaluation. Therefore, a new method should be provided to improve the evaluation accuracy.

In summary, this study combined the methods of field measurement and experimental evaluation, aiming to quantitatively and accurately reveal the correlations between indoor physical environment and satisfaction in shopping centers. In addition, the interactions among different factors were explored. And the research results can be utilized to improve the physical environment and consumers' satisfactory in shopping centers.

METHODS

Field measurement

Field measurement were conducted in four shopping centers in winter and summer of 2017, and the buildings' information was shown in Table 1. The field measurement parameters included the illuminance, CCT, air temperature and sound pressure level. Testing time were selected in business hours (10:00 AM to 10:00 PM) and the test information was shown in Table 2.

Table 1. Information of the four shopping centers.

Shopping Center	Built year	Total area (thousand m^2)	Total numbers of floor
H-S	2016	125	5
F-S	2016	92	6
S-S	2011	150	6
D-S	2014	113	7

Table 2. Test information.

Indoor environment	Parameter	Measurement instrument	Measuring range/ accuracy
Lighting	Illuminance	CL-500A	0.1-100,000 lx / ±2%
	CCT	CL-500A	>5 lx / -
Thermal	Temperature	TSI model 9545	-10-60°C / ±0.3°C
Acoustic	Sound pressure level	Nor140	15-140 dB A / -

Experimental evaluation

Overview of experiment

In order to find the correlations between physical environments and their satisfaction levels, a series of experiments were carried out in a laboratory with variable space and environment during January 2018 at Tianjin University (see Fig. 1 a)). A typical clothing store (see Fig. 1 b)) was simulated by an actual space, which total area was 48 m^2 and 4 meters high. During the experiments, illuminance and CCT were set as the variables and other physical parameters were the control variables. The range of illuminance and CCT were respectively 200 lx, 500 lx, 1000 lx, 1500 lx and 3000 Kelvin (K), 4500 K, 6000 K, and the air temperature and sound pressure level were set to 23C° and 75 dB A, which based on the previous field measurement in four shopping centers.

Participant and questionnaire

A total of 27 students from Tianjin University took part in the experiment and Table 3 shows the information of participants. To ensure the experimental results not affected by other factors, participants were instructed to wear the same type of clothing for each test. The information of the questionnaire consisted the satisfaction of lighting, thermal and acoustic environments. Satisfaction votes were used the ASHRAE (2013) 7-point scale as follows: strongly dissatisfied (-3), dissatisfied (-2), slightly dissatisfied (-1), neutral (0), slightly satisfied (1), satisfied (2), and strongly satisfied (3).

Table 3. The information of participants (mean value ± standard deviation).

Gender	Sample size	Age(y)	Height(cm)	Weight(kg)
Male	13	21.2±3.26	177.2±4.54	67.7±7.35
Female	14	20.2±3.38	162.2±7.53	53.4±6.50
Total	27	20.7±3.29	169.4±9.78	60.3±9.97

Experimental procedure
The satisfaction experiment lasted three weeks and the time was from 19:30 to 21:30 each day. Twelve types of lighting environments were selected in the experiment, and each environment condition lasted 20 minutes, including 9 minutes' adaptation time and 11 minutes' testing time (see Fig. 1 b) and c)). In adaptation time, participants were required to sit in a preparation room (500 lx; 4000 K) whose overall environment was constant. Meanwhile, the illuminance and CCT of the clothing store were changed through the controllable lighting system. In testing time, participants were asked to move around in the clothing store, and the first 10 minutes were utilized to experience the shopping environment and the last 1 minute to fill in the evaluation questionnaire. The experimental procedure for each day was shown in Fig. 1 d).
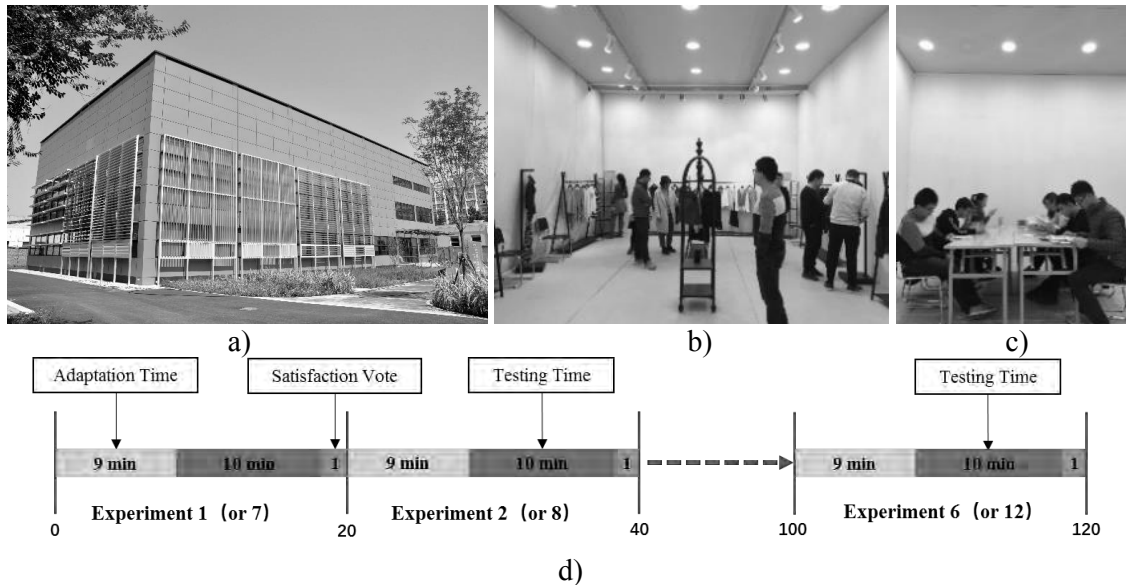

Figure 1. a) Variable space and environment laboratory, b) Testing time, c) Adaptation time, d) Experimental procedure.

RESULTS AND DISCUSSIONS
Objective environmental measurement
Fig. 2 shows the objective measurement results of illuminance, CCT, air temperature and sound pressure level of the 4 shopping centers. For lighting parameters, building H-S has the largest illuminance fluctuation between 431.8 lx and 2512.4 lx, and the average illuminance of the other three is between 224.9 lx to 1587.5 lx, which is mostly controlled above the lower limit of illuminance (300 lx) in Chinese standard GB50034 (2014) (see Fig. 2 a)). The result of CCT shows that building D-S has the largest fluctuation between 2828 K and 6398 K, and others are concentrated between 3000 K and 4000 K (see Fig. 2 b)).
The air temperature was respectively measured in summer and winter (see Fig. 2 c)). Through the comparison of measured levels and the thermal comfort standard GB50736 (2012) in

China, it is found that all shopping centers have a qualification rate above 70%, respectively H-S (72%), F-S (84%), S-S (91%), D-S (96%). In terms of indoor acoustic environment, S-S building has the smallest fluctuation between 68 dB(A) and 77 dB(A), while others stay at a high level and mostly fluctuate between 65 dB(A) and 85 dB(A) (see Fig. 2 d)). Through further analysis, the high noise level is mainly due to the background music and personal talking.
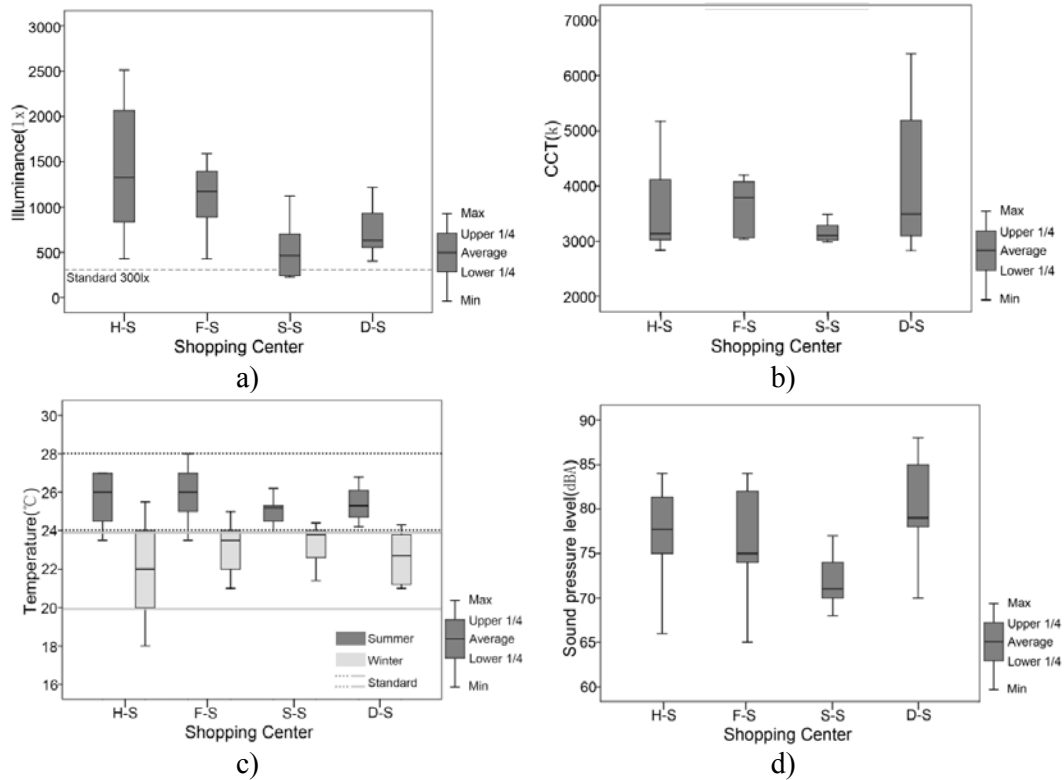

Figure 2. Objective measurements of indoor a) Illuminance, b) CCT, c) Temperature, d) Sound pressure level.

The impact of lighting parameters to satisfaction

The correlation analysis between lighting environment (illuminance, CCT) and people's satisfaction of lighting, thermal and acoustic environments is shown in Table 4. The correlation R value between illuminance and lighting satisfaction ranges from 0.532 to 0.648 (p<0.01), while the correlation R value between CCT and lighting satisfaction ranges from 0.204 to 0.292 (p <0.01 or p<0.05) in two illuminance environments (200 lx, 500 lx). However, there is no significant difference in the correlation of thermal and acoustic satisfaction with lighting environment (illumination, CCT).

Fig. 3 shows the relationship between the illuminance parameter and satisfaction level in three different CCT environments. Each point represents the mean value of the satisfaction level in the same illuminance and CCT environment. When the satisfaction level is larger than 0, it indicates that subjects are satisfied with the environment. Fig. 3 a) shows subjects are satisfied when the illuminance isn't lower than 500 lx, and the highest evaluation level occurs when the illuminance is 1000 lx and CCT is 4500 K. Moreover, between 200 lx and 1000 lx, participants feel more satisfied under the light of 6000 K and 4500 K than 3000 K. These result shows that Kruithof's rule (1941) of lighting comfort maybe not applied to the lighting environment preference for Chinese consumers. Fig. 3 b) and c) show that both thermal and

acoustic evaluation are satisfied and have small fluctuations in different lighting environments. The range of thermal satisfaction is from 0.39 to 0.87, and the acoustic satisfaction is from 0.69 to 1.13.

Table 4. Relationships between Lighting parameters and evaluation of satisfaction.

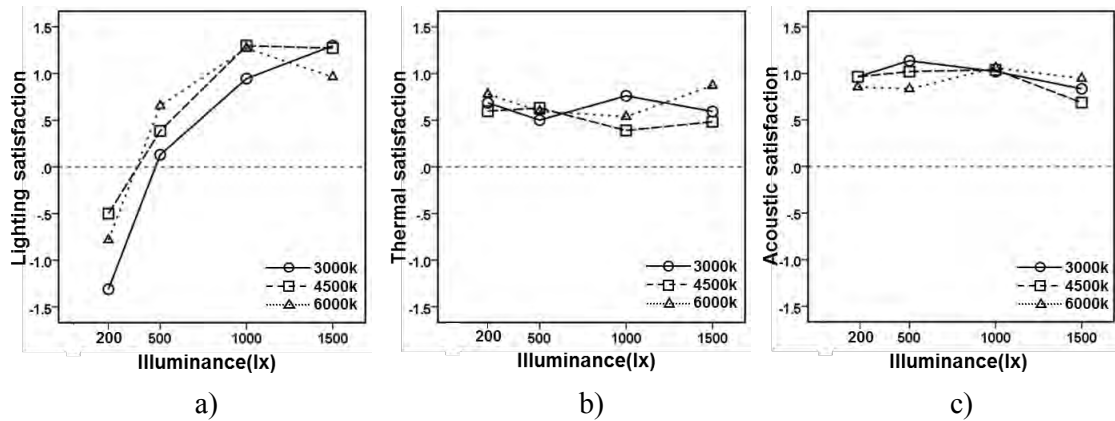| Lighting parameters	Conditions	Lighting	Thermal	Acoustic
Illuminance	3000 K	0.648**	0.003	-0.072
	4500 K	0.606**	-0.070	-0.103
	6000 K	0.532**	0.042	0.044
CCT	200 lx	0.292**	-0.044	-0.045
	500 lx	0.204*	0.045	-0.132
	1000 lx	0.146	-0.102	0.019
	1500 lx	-0.164	0.124	0.045

* $p < 0.05$; ** $p < 0.01$

Figure 3. Relationships between illuminance and a) Lighting satisfaction, b) Thermal satisfaction, c) Acoustic satisfaction.

The interaction of satisfaction level

Pearson correlation between lighting evaluation and satisfaction of thermal and acoustic environments is shown to be significant ($p<0.01$), and the correlation coefficient R is 0.250 and 0.219 respectively. Fig. 4 shows the voting results of thermal and acoustic environment at different lighting satisfaction level. When the lighting evaluation changing from "dissatisfied" to "satisfied", the dissatisfaction rate of thermal and acoustic is reduced by 34.47% and 17.74% respectively. The result shows that good lighting satisfaction can raise people's evaluation of thermal and acoustic environment in shopping centers.
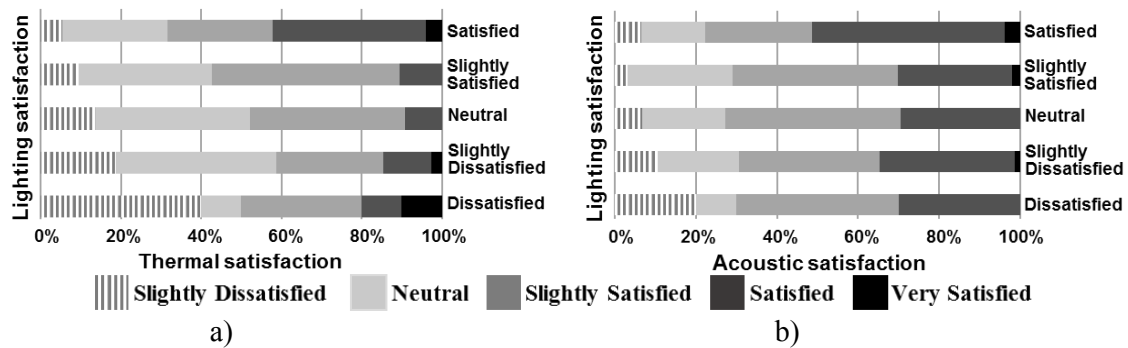
Figure 4. Satisfaction votes of a) thermal environment, b) acoustic environment under different lighting satisfaction votes.

CONCLUSIONS

On-site measurement shows that the range of illuminance was mostly from 500 lx to 1500 lx and the CCT was from 3000 K to 4000 K, the temperature qualification rate above 70% and the range of sound pressure level mainly from 65 dB A to 85 dB A. Satisfaction level experiment found the highest level of lighting satisfaction occurred when the illuminance was 1000 lx. From 200 lx to 1000 lx, subjects prefer the lighting environment with middle and high CCT. Moreover, the thermal and acoustic satisfaction were not directly influenced by lighting parameters; however, they had the interactions with lighting satisfaction, which showed that lighting environment would enhance the satisfaction levels of thermal and acoustic environments when it was satisfied.

ACKNOWLEDGEMENT

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