Fundamental Study on Psychological Evaluation of Low-frequency Flashing Lights from the Perspective of Urban Nightscape Lighting Design

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1. Introduction

With the development of electronic technology and Solid-State Lighting (SSL), including Semiconductor Light-Emitting Diodes (LED), organic Light-Emitting Diodes (OLED), and Polymer Light-Emitting Diodes (PLED), plenty of dynamic lighting are produced to meet different requirements of a variety of lighting environment. Besides the alerting signals which use the occulting lights and strobes, other dynamic lighting also began to be used for landmarks, billboards and nightscape decorations, which can allow designers to create extraordinary effects. Consequently, varied kinds of dynamic lighting can be widely found for outdoor lighting in recent years, particularly the flashing lights which go on and off characterized by the regular recurrence.

According to the field-survey in the downtown area of Beijing and Tokyo during 2011 and 2012, 375 dynamic lighting samples were recorded, among which more than 1/4 included flashing effect (Table 1.). And the flashing lights can be found in many different kinds of places in urban at night (Table 2.).

Table 1. The field-survey in downtown area

City	Dynamic lighting		
	Flashing effect	Multiple effect with flashing	Other effects (without flashing)
Beijing	28	21	131
Tokyo	41	17	137

Table 2. The places of flashing lights in urban at night

Commerce place	Amusement place	Others
billboard	karaoke bar	landmark
department store	cinema	public park
shopping street	theatre	square
convenience store	game center	road beacon
exclusive shop	night club	parking exit
cafe	casino	landscape decoration
restaurant	gymnasium	fountain
hotel		

Dynamic lighting can create expressive effects and capture more attentions, as it is also believed that when LED is flashing, it takes less energy but works much more effectively[1]. However, it's worth highlighting that there are more problems and potentially dangerous in this field with extremely use of dynamic lighting. For example, inappropriate design can cause visual stress (sometimes called 'Meares-Irlen Syndrome' or 'Scotopic Sensitivity Syndrome') that brings the experience of unpleasant visual symptoms and can also evoke visual distraction that disturbs the comfort and continuity environment[2], what is more, repetitive flashing effects, such as individual strobes or small groups of strobes, are capable of inducing a photosensitive epileptic seizure[3]. Therefore further study and more attention on this field are necessary.

2. Background

Studies on flashing lights have a long history. In the 17th century, a Belgian scientist, Plateau, used the flickering of light through a strobe wheel to study the diagnostic significance of the flicker fusion phenomenon[4]. From the mid-1930s, modern scientific research began to study on this field and a British neuroscientist Gray Walter used strobe lights to create visual stimulation and published the results that the brain wave pattern of the whole cortex was changed when exposed to flashing lights[5].

In recent decades, the research of potential hazard of flashing lights for the photosensitive epilepsy and the perception of visual warning systems began to grow[6,7]. Graham Harding noted that "A flash is a potential hazard if it has luminance $\geq 20 cd/m^2$, occurs at a frequency of ≥ 3 Hz [8]." In the UK the use of flashing stroboscopes at public displays or performances are restricted by guidelines issued by the Health and Safety Executive (HSE). It is believed that a flashing light is limited to a maximum of 4 flashes/s[9]. And in the Event Safety Guide (HSG195) which mainly dealing with outdoor event, HSE also gives the advice on strobe lights that the frequency should below 4 Hz and if multiple units are used they should be synchronized[11].

Also the special alerting lights used for construction, maintenance and emergency vehicles to warning and anti-collision have been studied in many countries. The relative effectiveness of flashing lights involving various combinations of varying mode, color and frequency was explored[6,11].

3. Aim and method

The most previous studies of the flashing lights are focused on visual effectiveness and potential hazard which occur at relative high frequency (greater than 3Hz). Research is quite limited on the low-frequency from the perspective of lighting design and urban nightscape lighting plan on this field. In order to get deeper understandings of the low-frequency flashing lights to obtain more comfortable visual environment and offer some advices to set up guideline for urban nightscape lighting design, additional study is needed.

In this paper study was conducted to investigate implied emotion of low-frequency flashing lights by examining different CG samples. It is a valid approach to understand people's emotion and feeling by means of psychology experiment.

4. Experiment

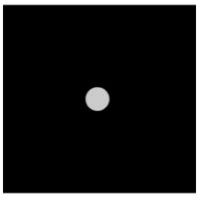
4.1. Design

The experiment took place in a quiet darkroom laboratory to avoid ambient light and sound interference. Twenty students (11 males and 9 females) with normal visual perception and without photosensitive epilepsy participated in this experiment. Their ages ranged from 20 to 30 years.

The patterns were produced to stimulate the point flashing light by Flash Professional CS4. The variables of the experiment patterns are included frequency (design by software), luminance (adjusted by software and projector) and visual solid angle (determined by the different surface of the dot). Each variable is divided into three different levels (Table 3 lists the details), giving altogether 27 different patterns.

Subjects were asked to rate each pattern once in relation to the seven adjectives separately on 7-point Likert-type scales in Japanese or Chinese according to their feelings. The seven adjectives scalar are uncomfortable (不快な，不舒适的), lively (にぎやかな，热闹的), outstanding（目立つ，醒目的）, glaring（眩しい，炫目的）, urgent（切迫感，紧迫的）, bustle（うるさい，喧闹的） and preferable （好きな，喜欢的）. To minimize order effect and fatigue, the visual samples were randomly presented for each subject.

Table 3. The three levels of variables used in the experiment

CG Samples				
Pattern image	Variable	Level		
		1	2	3
	Frequency（Hz）	0.33	1	3
	Luminance（cd/m^2）	12.7	53.6	223
	Visual Solid Angle	0.0003	0.0028	0.0253
	Average Background Luminance（cd/m^2）	0.58	0.81	2.76

All the simulated CG samples were presented on a floor projection screen by a projector. Subjects sat in front of the floor projection screen at a distance of 2500 mm and needed to set his jaw in a fixed position to keep sightline (Fig.1).

Fig. 1. The sketch of the basic psychology experiment

4.2. Procedure

Subjects were briefed about the purpose, method and procedure during darkness adaptation at the beginning of the experiment. In order to make them familiarized themselves with the procedure, a few practice trials were done before beginning the actual experimental series. After explanation and darkness adaptation, the participants were required to close their eyes to initiate the experiment. When target pattern was presented, they were asked to open eyes to see it for 10 seconds and then closed their eyes again to rate the perceived level of the stimulus on a 7-point Likert scale on the dimensions of seven emotional adjectives. After that, the participants were asked to reopen their eyes to do next trials. There were 27 trials to evaluate 27 patterns and a five-minute break was given after evaluating 13 target patterns. Each subject took about 50 minutes to complete the full experiment.

4.3 Results

Data analysis of this psychological experiment is very essential to investigate how the three variables of flashing lights vary together to affect people's emotion. In this paper, IBM SPSS Statistics and JMP are used to describe and summarize the ways in which variables

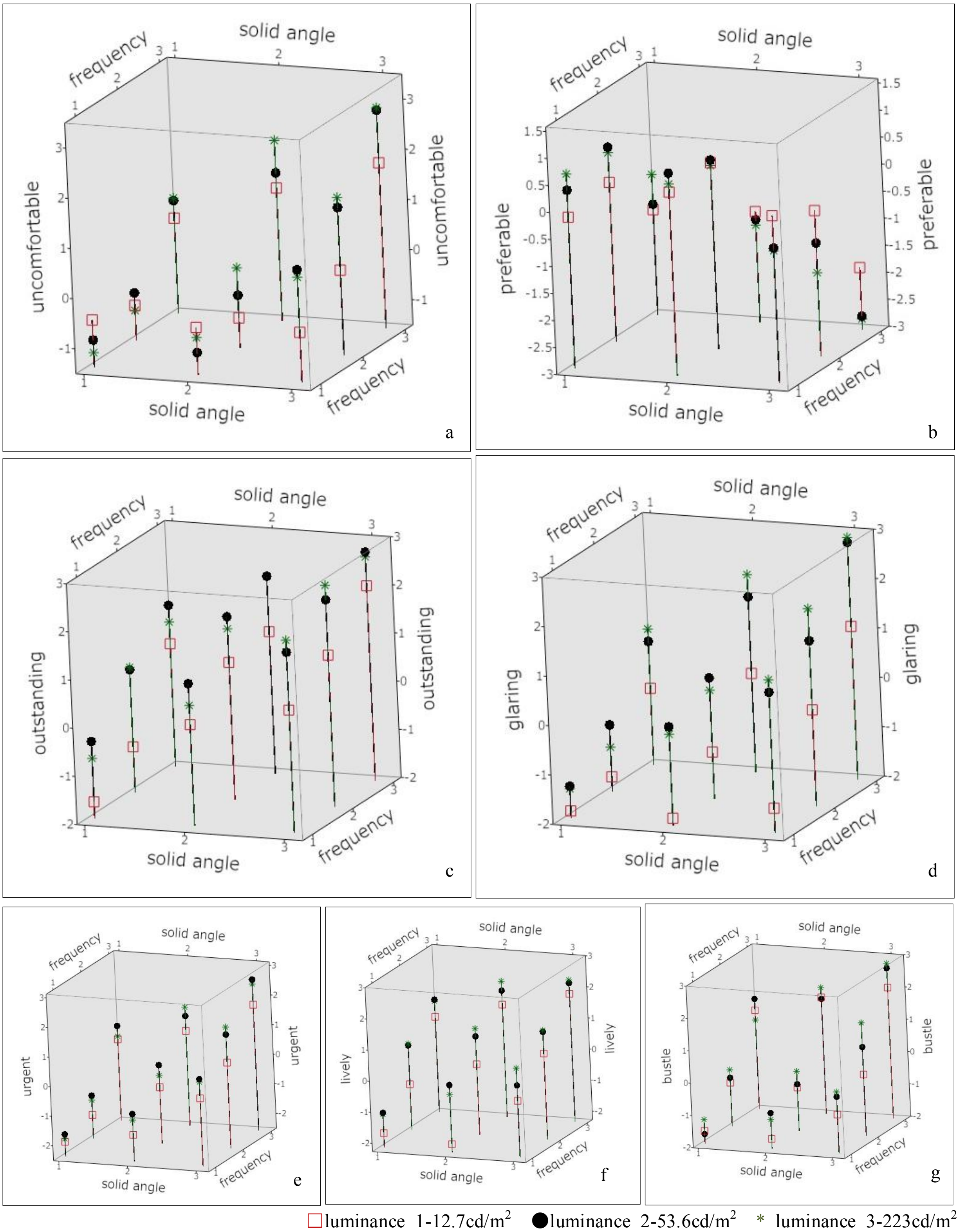
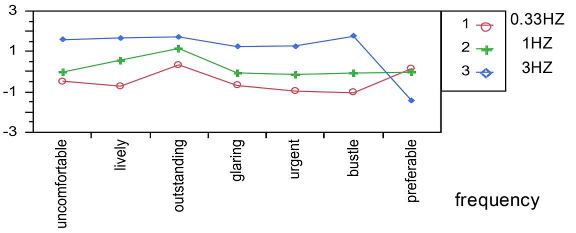
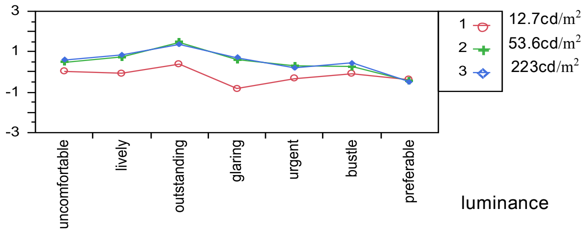


Fig. 2 (a-g) 3D scatter plots of the experiment vary together.

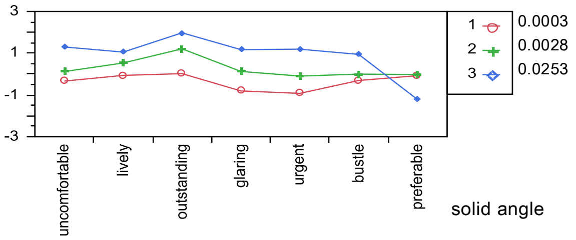
The 3D scatter plots of the experiment (Fig. 2) enable to release the detailed results of the perceived emotions of uncomfortable, lively, outstanding, glaring, urgent, bustle and preferable on the different three level of each variable of the basic experiment intuitively. The 3D scatter plots also show that perceived emotions are relatively strong when the frequency, luminance and visual solid angle are in high level (level 3).



Test	F Value	Num df	Den df	Pr>F)
F-Test	35.7722	2	20	<.0001*



Test	F Value	Num df	Den df	Pr>F)
F-Test	8.82051	2	20	<.0001*



Test	F Value	Num df	Den df	Pr>F)
F-Test	22.5939	2	20	<.0001*

Fig. 3 Least Squares Means plot of the experiment

In order to test the validity and significant effects of the three hypotheses (frequency, luminance and visual solid angle), the main and interaction effects were examined with multivariate analysis of variance (MANOVA). The main effects of MANOVA are exhibited in Fig. 3. The perceived emotions effects of frequency (F=35.77) are significantly greater than that of visual solid angle (F=22.59) and luminance (F=8.82). In condition with little or no ambient light (background luminance less than 3cd/m^2), the perceived emotion between luminance2 (53.6cd/m^2) and luminance3 (223cd/m^2) is not so significance. It is also can be shown that if the frequency is relatively low (below 1Hz) or the visual solid angle is relatively small (less than 0.0028) the emotion of uncomfortable and preferable will not have significant differences.

Table 4. Tests of Between-Subjects Effects for MANOVA

Source	Dependent Variable	Type III Sum of Squares	Mean Square	F	Sig.
frequency * solid angle	uncomfortable	16.261	4.065	2.229	.065
	lively	7.953	1.988	1.342	.253
	outstanding	13.970	3.492	3.074	.016
	glaring	4.844	1.211	.788	.533
	urgent	6.270	1.568	1.016	.399
	bustle	1.978	.494	.355	.840
	preferable	9.455	2.364	.879	.476
luminance * solid angle	uncomfortable	38.661	9.665	5.300	.000
	lively	6.138	1.535	1.036	.388
	outstanding	4.200	1.050	.924	.449
	glaring	42.532	10.633	6.921	.000
	urgent	7.875	1.969	1.275	.279
	bustle	11.630	2.907	2.088	.081
	preferable	34.263	8.566	3.184	.013
frequency * luminance	uncomfortable	10.889	2.722	1.493	.203
	lively	7.251	1.813	1.224	.300
	outstanding	4.736	1.184	1.042	.385
	glaring	2.812	.703	.458	.767
	urgent	.451	.113	.073	.990
	bustle	9.709	2.427	1.744	.139
	preferable	1.996	.499	.186	.946

Based on observed means.

Table 5. The results of correlation

		Solid angle	frequency	luminance
uncomfortable	Pearson Correlation	.556(**)	.696(**)	.191
	Sig. (2-tailed)	.003	.000	.340
	N	27	27	27
lively	Pearson Correlation	.387(*)	.829(**)	.314
	Sig. (2-tailed)	.046	.000	.111
	N	27	27	27
outstanding	Pearson Correlation	.710(**)	.502(**)	.353
	Sig. (2-tailed)	.000	.008	.071
	N	27	27	27
glaring	Pearson Correlation	.589(**)	.573(**)	.452(*)
	Sig. (2-tailed)	.001	.002	.018
	N	27	27	27
urgent	Pearson Correlation	.658(**)	.696(**)	.167
	Sig. (2-tailed)	.000	.000	.404
	N	27	27	27
bustle	Pearson Correlation	.387(*)	.865(**)	.169
	Sig. (2-tailed)	.046	.000	.401
	N	27	27	27
preferable	Pearson Correlation	-.482(*)	-.675(**)	-.042
	Sig. (2-tailed)	.011	.000	.836
	N	27	27	27

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

From Table4， it can be concluded the interaction effect of this psychology experiment between the three variables (frequency, luminance and visual solid angle) was no significant except frequency*solid angle -- outstanding, luminance *solid angle – uncomfortable, luminance*solid angle – glaring and luminance*solid angle -- preferable.

To quantify relationships, Pearson Correlation was computed as the ratio of covariance between variables and emotions. Table 5 shows correlation results of the basic experiment. Generally, if absolute value of the correlation coefficient is above 0.8, the strength of relationship is considered pretty strong, at 0.6 to 0.8 is considered strong and below 0.2 is considered very weak (Significance level was set at P=0.05)[12]. It indicates that the relationship of frequency-noisy and frequency-lively is pretty strong and the relationship of solid angle-outstanding, solid angle-urgent, frequency-uncomfortable, frequency-urgent and frequency-preferable are also strong; rather, the relationship of luminance-preferable, luminance-bustle, luminance-uncomfortable and luminance-urgent is very weak. And there is a negative correlation between the three variables and perceived preferable.

5. Conclusion

The purpose of this experiment is to investigate how frequency, luminance and visual solid angle of low-frequency flashing lights vary together to affect people's emotion. Through this basic psychological experiment, the perceived emotions can be examined and the influence of variables can be detected.

MANOVA and Pearson Correlation analysis supported : 1. The effects of the three variables on perceived emotions are significant, and among them the effects of frequency are significantly greater than that of luminance and visual solid angle. 2. It is negative correlation between the three variables and perceived like as well as positive correlation between the variables and perceived uncomfortable, lively, outstanding, glaring, urgent and noisy. 3. When the frequency is at 3Hz, it will trigger uncomfortable and bring dislike feeling strongly. When the frequency below 1Hz or the visual solid angle is less than 0.01, the differences in effects on uncomfortable and like are not significant. Also when the luminance is higher than 55cd/m^2, the differences in effects on all perceived emotions are not significant.

As previous research is quite limited, the fundamental study can help us to do further study on the real scene of dynamic lighting. It will make designers get deeper understandings of the low-frequency flashing lights as well as other kinds of dynamic lightings. From the perspective of lighting design and urban nightscape lighting plan, this research also can offer advices to obtain more appropriate design.

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都市夜間照明に向けた低周波点滅形照明の心理評価に関する基礎的研究

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キーワード：点滅光　輝度　周波数　視角　照明設計

照明技術が発展するとともに、多くの動的照明が都市の夜間照明に用いられるようになった。その中でも様々な場所で多く見られるものは点滅形の動的照明である。点滅で変化を創り出す照明は、デザイナーに豊かな表現手段を提供でき、変化のない照明に比べて印象が強い。しかし、点滅形の動的照明には多くの潜在的な問題があり、適切に使用されなかった場合、視覚作業の障害、視覚上の疲労をもたらす可能性があり、さらに高周波の点滅光が光過敏性てんかんの発作を誘引してしまうこともある。既往研究は主に高周波点滅光（3Hz 以上）に関するものであり、夜間照明設計を行う立場からの低周波点滅形照明に関する研究はほとんどない。

本研究では CG を用いて点滅変化する光のシミュレーションを行い、異なる点滅光が人間の心理に及ぼす影響を印象評価実験によって検討する。実験では点滅光の輝度、周波数、視角をそれぞれ三つのレベルにわけ、合計 27 通りの実験パターンを作成した。実験データからは主に以下に示す三点がわかった。１：点滅光の輝度、視角と周波数はすべて人の心理に影響し、周波数が心理に及ぼす影響がもっとも大きい。２：輝度、周波数、視角は「不快な，にぎやかな，目立つ，眩しい，切迫感，うるさい」という心理評価と正の相関関係があり、「好きな」と負の相関関係が見られた。３：輝度を 53cd/m² 以上で設定したとき、すべての心理評価に対して他の要素が与える影響に殆ど差が見られなかった。また点滅光の周波数が 3Hz であるとき、「不快な，好きな」を強く感じ、周波数を 1Hz 以下で設定したときと、視角を 0.0028 未満に設定したときは、「不快な，好きな」に対して他の要素が与える影響に大きな差が見られなかった。

今後より実際的な場面での検討を行ろことにより、合理的な点滅光の使い方を提案できると考える。

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