Reaction Time based Model for Mesopic Photometry

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ABSTRACT: Reaction time under different lighting source was obtained. The influence of luminance, contrast and eccentric angle on the reaction time were investigated. The relation between L_m and x were built using spectral luminous efficiency function V(λ), the ratio of light flux of the photopic vision and scotopic vision (r = s/p) equation. The experimental data were fitted to an easier linear equation and a new photopic vision model was obtained and this model could be described by an equations.

KEYWORD: Reaction time; luminous efficiency function; photopic vision

1 INSTRUCTIONS

Photometry combines the optical properties and radiation energy of the lighting source by spectral luminous efficiency function.[1~2] The visibility function is defined in order to express the difference of the eye's sensitivity for different radiation, which can compare the strong and weak of vision inducing by two radiators with different wavelength.[3] According to the International Commission on illumination (CIE), the vision over level of luminance 10 cd/m^2 is defined photopic vision and the vision below level of luminance 10^{-3} cd/m^2 is defined scotopic vision. In fact, levels of luminance of much outdoor lighting and some indoor lighting are at the region of 0.001~3cd/m^2, which is defined mesopic vision. Especially, the road lighting belongs to the mesopic vision region.[4~5] Therefore, more and more attentions are paid on the mesopic vision and the public voice of establishing photometry standard based on the mesopic vision becomes higher and higher.[7~8]

Two main methods are used to measure spectral luminous efficiency function including heterochromatic brightness matching methods and scintillation method.[9] However, it is difficult to compare the brightness of two different colors light when the heterochromatic brightness matching method is used. The scintillation method is better than the heterochromatic brightness matching method and it matches the additivity in the brightness region of photopic vision. But it becomes complex at mesopic vision state using scintillation method. The main method of building mesopic vision function is vision efficacy method in the international.[10] The spectral luminous efficiency function can be represented by a certain combination of photopic vision function V(λ) and scotopic vision function V'(λ) by some mathematical treatment and the combined formula.[11]

There are three main mesopic vision model based on the vision efficacy method including X model, MOVE model and S model. In this paper, we investigated the influence of the luminance, contrast and eccentric angle on the reaction time. A new mesopic vision model was built based on the measure of familiar five lighting source.

2 THE INFLUENCE OF ENVIRONMENTAL CONDITION ON THE REACTION TIME

2.1 *The influence of luminance on the reaction time*

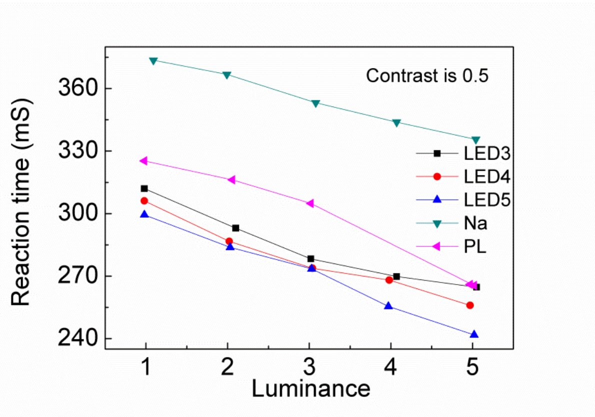

Figure 1. The effect of luminance on RT for different colors when L=3 cd/m^2.

Fig.1 shows the effect of background luminance on reaction time when contrast is 0.5 under five kinds of lighting source. It can be seen from the figure that reaction time decrease with luminance increase from 1 cd/m^2 to 5 cd/m^2.That is to say, vision efficacy increase with luminance increase. At the same brightness, the reaction time is longer than others when Sodium lamp is used as lighting source. While it is shorter when LED lamps are used as lighting source.[12]

2.2 *The influence of contrast on the reaction time*

The influences of contrast on the reaction time for the five lighting source when the luminance is 3cd/m^2 and Fig.2 gives the relation curve. The reaction time increases with the contrast increase from 0.3 to 0.8, which indicates that higher contrast is not benefit to the reaction of people.

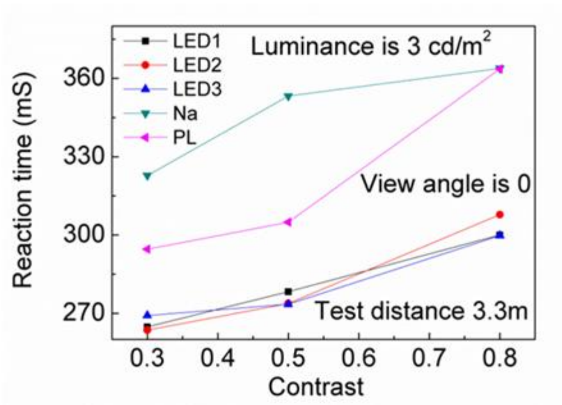

Figure 2. The effect of contrast on RT for different colors when L=3 cd/m^2.

2.3 *The influence of eccentric angle on the reaction time*

Generally, the eccentric angle has greatly effect on the reaction time. It can be seen from Fig.3 that the reaction time increase when eccentric angle is turn to 10^o from 0^o under all the five lighting sources.

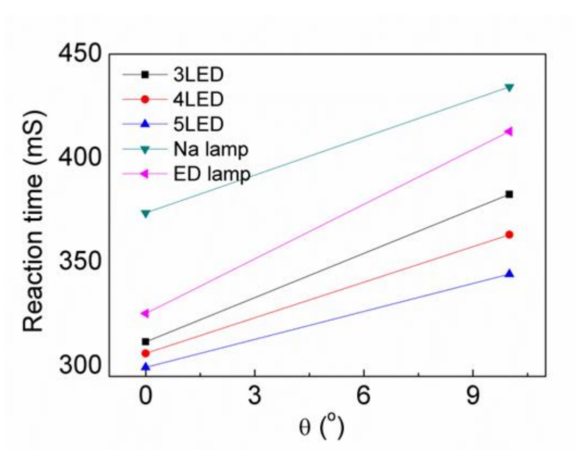

Figure 3. The effect of contrast on RT for different colors when L=3 cd/m^2.

3 BUILDING OF MESOPIC VISION MODEL

The relation between luminance and radiance can be connected by spectral luminous efficiency function V(λ) like Eq.1:[13]

$$L=K_m\int L_{e,\lambda}\cdot V(\lambda)\cdot d\lambda \quad (1)$$

where L is luminance, $L_{e\lambda}$ is radiance, $V(\lambda)$ is the spectral luminous efficiency function of eyes, K_m is the maximum spectral luminous efficacy.

The spectral properties of lighting source can be expressed by spectral energy distribution. In the mesopic vision, it can be characterized by the ratio of light flux of the photopic vision and scotopic vision (r = s/p).[14]

$$r=\frac{S}{P}=\frac{1700\cdot\int L_{e,\lambda}\cdot V'(\lambda)d\lambda}{683\cdot\int L_{e,\lambda}\cdot V(\lambda)d\lambda} \quad (2)$$

So the photopic vision brightness L_m can be defined by Eq.3[15]

$$L_m=K_m(x)\int L_{e,\lambda}V_m(\lambda)d\lambda \quad (3)$$

The photopic vision function can be described by Eq.4[16]

$$V_M(\lambda)=xV(\lambda)+(1-x)V'(\lambda) \quad (4)$$

where L_m is the photopic vision brightness; V(λ) is photopic vision, V'(λ) is scotopic vision, x is a variable in region of 0~1. It corresponds to photopic vision conditions when x=1, while it corresponds to scotopic vision when x=0. It belongs to photopic vision when $0<x<1$. The relation between L_m and x ban be derived by above function and expressed by Eq.5 or Eq.6:

$$L_m=\frac{x\cdot L_p+0.402\cdot(1-x)\cdot r\cdot L_p}{x+0.402\cdot(1-x)} \quad (5)$$

$$x=\frac{0.402\cdot r\cdot L_p-0.402\cdot L_m}{0.598L_m-L_p+0.402\cdot r\cdot L_p} \quad (6)$$

in which L_p is photopic vision brightness.

In this experiment, five kinds of lamps are selected as lighting source including Na lamp, electrodeless lamp and three LED with different color temperature. More than 3675 data are obtained in the experiment. According to above equation and the calculation method and Zhang etc, we obtain a series of x and L_m values and show them in Table 1.

Relation of L_m and x is critical to build a photoic vision model by visual efficacy experiment. A succinct linear equation (Eq.7) is use to fit the relation of L_m and x. Fig.4 gives the experimental data and fitting line.

$$x=0.166+0.08L_m \quad (7)$$

Eq.7 is substituted in Eq.5 and a unary quadratic equation (Eq.8) will be obtained:

$$0.112L_m^2-(0.169-0.08L_p-0.032\cdot r\cdot L_p)L_m+(0.335\cdot r\cdot L_p-0.166L_p)=0 \quad (8)$$

Table 1 x and L_m values for five kinds of lighting source when C=0.5

Lighting source		**Na lamp**	**LED1**	**LED2**	**LED3**	**Electrodeless lamp**
r(s/p)		0.594	1.393	1.586	1.718	1.999
L=1cd/m^2	L_m	0.551	1.752	1.996	2.351	2.981
	x	0.13	0.182	0.494	0.312	0.65
L=2cd/m^2	L_m	0.733	3.382	4.334	4.398	2.657
	x	0.396	0.462	0.528	0.44	0.99
L=3cd/m^2	L_m	1.242	5.305	6.081	3.986	4.109
	x	0.286	0.528	0.462	0.704	0.902
L=4cd/m^2	L_m	1.371	7.896	9.125	9.602	6.145
	x	0.396	0.704	0.616	0.55	0.572
L=5cd/m^2	L_m	1.701	9.698	11.299	13.129	7.726
	x	0.396	0.66	0.594	0.638	0.55

Solve the Eq.8 and the expression of L_m will be obtained:

$$L_m=-\frac{0.169-0.08L_p-0.032\cdot r\cdot L_p}{0.224}+\frac{\sqrt{(0.169-0.08L_p-0.032\cdot r\cdot L_p)^2-(0.15\cdot r\cdot L_p-0.07L_p)}}{0.224}$$

According to result, we can calculate the value of L_m through measuring L_p. A photopic vision model based on the five common lighting sources can be obtained and it can describe the various of x in the region of 0.001-10cd/m^2. This model can be expressed by an equations:

$$\begin{cases} V_{mes}(\lambda)=XV(\lambda)+(1-x)V'(\lambda) \\ r=\dfrac{S}{P}=\dfrac{1700\cdot\int L_{e,\lambda}\cdot V'(\lambda)d\lambda}{683\cdot\int L_{e,\lambda}\cdot V(\lambda)d\lambda} \\ x=0.166+0.08L_m \\ L_m=-\dfrac{0.169-0.08L_p-0.032\cdot r\cdot L_p}{0.224}+\dfrac{\sqrt{(0.169-0.08L_p-0.032\cdot r\cdot L_p)^2-(0.15\cdot r\cdot L_p-0.07L_p)}}{0.224} \end{cases}$$

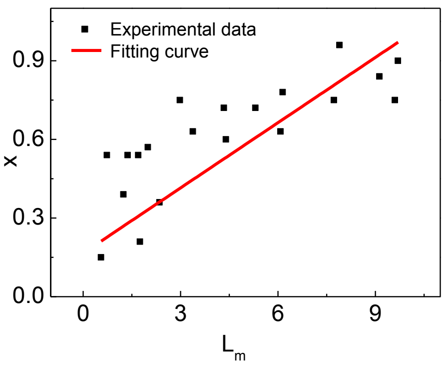

Figure 4. Relationship between Lm and x.

4 CONCLUSIONS

In a word, reaction time under different lighting source has been obtained. At the same brightness and contrast, the reaction time is longer than others when Sodium lamp is used as lighting source. Higher contrast is not benefit to the reaction of people. Reaction time increase when eccentric angle increase under all the five lighting sources. The relation between L_m and x are built by spectral luminous efficiency function V(λ), the ratio of light flux of the photopic vision and scotopic vision (r = s/p) equation. The experimental data are fitted to a linear equation and a new photopic vision model is obtained and this model can be described by an equations.

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