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RELATIVE LUMINOSITY GENERATED BY THE COLOURS OF THE CRT

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Abstract

This paper describes a computer-controlled method presented on a CRT, which is capable of defining the relative luminosity generated by the primary colors of the monitor. The relative luminance ratio of the different primary colors of the monitor generating the same luminance sensation has been identified. The method is based on heterochromatic photometry. Theoretical calculation of the luminosity generated by the primary colors is also presented in the paper. Analysis shows little difference between theoretical calculation results and actual measurement data. An interesting byproduct of the theoretical calculation is that the additive mixture of the equal luminosity primary colors results to purple colour rather than white. At the end the feasibility of a color vision test based on individual luminance sensation compensation and carried out on a computer-controlled color CRT is discussed.

Keywords: CRT, relative luminosity.

1. Theoretical and Experimental Method for Identification of Relative Luminosity Sensation on CRT monitor

1.1. Calibration of a CRT Monitor

In order to achieve accurate colorimetric results we carried out both spectral and photometric calibration on the CRT monitor we used for our experiments. First we measured the spectral power distribution of the three primary monitor colors meanwhile setting their intensity to the maximum. Then we measured the gamma characteristics of the monitor. The spectral calibration was carried out with a Prichard spectroradiometer and the photometric calibration was done using a Cosilux photometer. The monitor we used was a 17” NOKIA driven by a PII processor PC through a 3×8 bit color resolution MATROX video card.

1.2. Calculation of the Relative Luminance Sensation on CRT Monitors

The luminance sensation is defined by the spectral power distribution of the light reaching our eye (color stimulus function) and spectral luminous efficiency function.

In our case the spectral power distribution of the light arriving to the eye is built from the primary colors of the monitor and their additive mixtures. The spectral luminous efficiency function is derived from the commonly accepted CIE standard [1] as shown in the following equation (*Eq.* (1))

$$L_{Red} = \int_{350}^{800} V(\lambda) \cdot \varphi_{Red}(\lambda) \mathrm{d}\lambda,$$

$$L_{Green} = \int_{350}^{800} V(\lambda) \cdot \varphi_{Green}(\lambda) \mathrm{d}\lambda,$$

$$L_{Blue} = \int_{350}^{800} V(\lambda) \cdot \varphi_{Blue}(\lambda) \mathrm{d}\lambda. \tag{1}$$

Based on these calculations the luminance sensation ratio of the three primary colors – at their maximal intensity – is $L_{Red} : L_{Green} : L_{Blue} = 0.24 : 1 : 0.13$. However, if we wish to know how to set the intensity of the three primary colors in order to achieve that they are stimulating equal luminance sensation in the human eye, we have to solve the following equation (*Eq.*(2)):

$$R\cdot \int_{350}^{800} V(\lambda)\cdot\varphi_{Red}(\lambda)\mathrm{d}\lambda = G\cdot \int_{350}^{800} V(\lambda)\cdot\varphi_{Green}(\lambda)\mathrm{d}\lambda = B\cdot \int_{350}^{800} V(\lambda)\cdot\varphi_{Blue}(\lambda)\mathrm{d}\lambda, \tag{2}$$

where R, G and B parameters are defining the relative ratio of the luminance of the primary monitor colors. Doing the calculations we get the relative luminance ratio of the primary monitor colors stimulation equal luminance sensation as $R : G : B = 0.54 : 0.13 : 1$.

1.3. An Interesting 'Byproduct' of the Calculations

If we additively mix the primary colors generating equal luminous sensation we get purple color. If we take a close look at the receptor stimuli generated by this mixed color this result will not be surprising. The calculation shall be done in two steps. At the first step we assume that the eye is adapted to the white color presented on the monitor. We shall allow this assumption because the experimental environment is a dark room where the only light source is the monitor. From the von Kries' law we can calculate how the status of the eye – adapted to the monitor white – modifies the spectral sensitivity functions (*Eq.* (3)):

$$k_L \int_{350}^{800} \varphi_W(\lambda) l(\lambda)\mathrm{d}\lambda = k_M \int_{350}^{800} \varphi_W(\lambda) m(\lambda)\mathrm{d}\lambda = k_S \int_{350}^{800} \varphi_W(\lambda) s(\lambda)\mathrm{d}\lambda,$$

$$\varphi_w(\lambda) = \varphi_R(\lambda) + \varphi_G(\lambda) + \varphi_B(\lambda), \tag{3}$$

where $\varphi_w(\lambda)$ is the spectral energy distribution of the monitor white, $l(\lambda)$, $m(\lambda)$, $s(\lambda)$ are the spectral sensitivity functions taken from the Smith–Pokorny model, [2] and k_L, k_M, k_S are the adaptation constants.

In the second step of the calculation we define the stimulation status of the L, M and S (long, medium and short wave sensitive) receptors after reaching the adaptation status (*Eq.* (4)):

$$L = k_L \int_{350}^{800} [R \cdot \varphi_{Red}(\lambda) + G \cdot \varphi_{Green}(\lambda) + B \cdot \varphi_{Blue}(\lambda)] \cdot l(\lambda) \mathrm{d}\lambda,$$

$$M = k_M \int_{350}^{800} [R \cdot \varphi_{Red}(\lambda) + G \cdot \varphi_{Green}(\lambda) + B \cdot \varphi_{Blue}(\lambda)] \cdot m(\lambda) \mathrm{d}\lambda,$$

$$S = k_S \int_{350}^{800} [R \cdot \varphi_{Red}(\lambda) + G \cdot \varphi_{Green}(\lambda) + B \cdot \varphi_{Blue}(\lambda)] \cdot s(\lambda) \mathrm{d}\lambda. \tag{4}$$

From the calculation the $L : M : S$ ratio turns out to be $0.49 : 0.50 : 1$, which is indeed matching with the stimuli of a purple color.

1.4. Measurement Method to Define Relative Luminance Sensation on CRT Monitor

Several procedures are referenced in the literature for identifying the spectral luminous efficiency function [3], [4]. There is much less reference on luminance sensation stimulated by the primary colors of a monitor [5]. The yet known methods are based on heterochromatic flicker photometry or ‘minimum motion’ principles. In our method the subject of the experiment defines the relative luminance sensation stimulated by the primary colors of the monitor with the method of direct heterochromatic photometry. The method applies a circle or square shaped test pattern positioned in the middle of the CRT. The size of the pattern and the distance between the observer and the screen is set to allow seeing the test pattern in 10° view field. The pattern is split in half, and both halves represent one of the three primary colors. The task of the observer is to set the intensity of the presented colors until the luminosity of both parts seems to be equal for him/her.

A set of measurements consists of three settings. The two sides of the test pattern are blue-green, blue-red and red-green. For all three couplings the observer has to set luminance equilibrium between the two parts. For practical reasons the luminance of one of the halves is preset, and the observer or an assistant changes the intensity of the other half until the luminance sensation generated by the two halves seems to be equal for the observer. The measurement protocol was to present the brightest possible blue on one side and ask the observer to match first the green and the red colors presented in the other half of the pattern. In the third step the previously set red was presented on the fixed side, and the observer was asked to match the green color presented on the other side. If the measurement is carried out properly the red/green ratio calculated from the first two settings shall be in close approximation to the red/green ratio actually measured in the third step. If these two ratios differ from each other significantly it might indicate an improperly conducted measurement set. It shall be noted that an observer lacking the knowledge of basic coloristics might have difficulties understanding the task. The observer might find the method too subjective.

1.5. Color Vision Test Based on Correction of Relative Luminance Sensation

Eight percent of male and half a percent of female population is color vision deficient. This is mostly an inherited genetic defect therefore it is important to recognize it as early as possible. There are several color vision tests developed, most of them are based on the measurement of color discrimination ability, because it is well known that the color vision deficient person's color discrimination ability is worse than a normal color vision person's [6]. During the tests based on color discrimination test subjects have to differentiate between the same luminance sensation but different hue colors. It is essential to apply colors with identical luminance sensation, otherwise the test person might have been able to differentiate between the presented colors not based on hue but based on luminance. Most of the tests are using colors of the confusion lines, because failing to discriminate these colors gives an indication on the type of the color deficiency as well [7], [8]. Colors and confusion lines described in the CIE xy color system present equal luminance sensation for the normal color vision people but present different luminance sensation for color vision deficient people. Color vision tests based on individual relative luminance sensation correction would be sufficient to overcome this issue, but it is not feasible to realize it with printing technology. Therefore printed pseudo-isochromatic plates are masked with randomly changing luminance dots. The increasing accessibility of computers and color monitors provides a platform for color vision tests based on relative luminance sensation correction [10]. That is why it is important to develop methods suitable for identifying relative luminance sensation on monitors.

2. Measurement Results

Applying the above-described method we measured 6 individuals. Prior to the actual test all of them were tested with Ishihara and Velhagen tests, PDT-2000 equipment [9] and a computer controlled color vision test [10] and all of them were found to have normal color vision. The actual test was carried out in a dark room and special care was taken to make sure that the subjects' eye was adapting to the monitor's white color only. Six measurement series were taken for all subjects; every series consisted of 3 individual measurements. In cases when the red/green ratio calculated from the blue/red and blue/green ratios did not match with the directly measured red/green the measurement was repeated. The average of the measured ratios was in close approximation to the theoretically calculated values. *Figure 1* shows the theoretical values and the average of the actually measured relative luminance ratios.

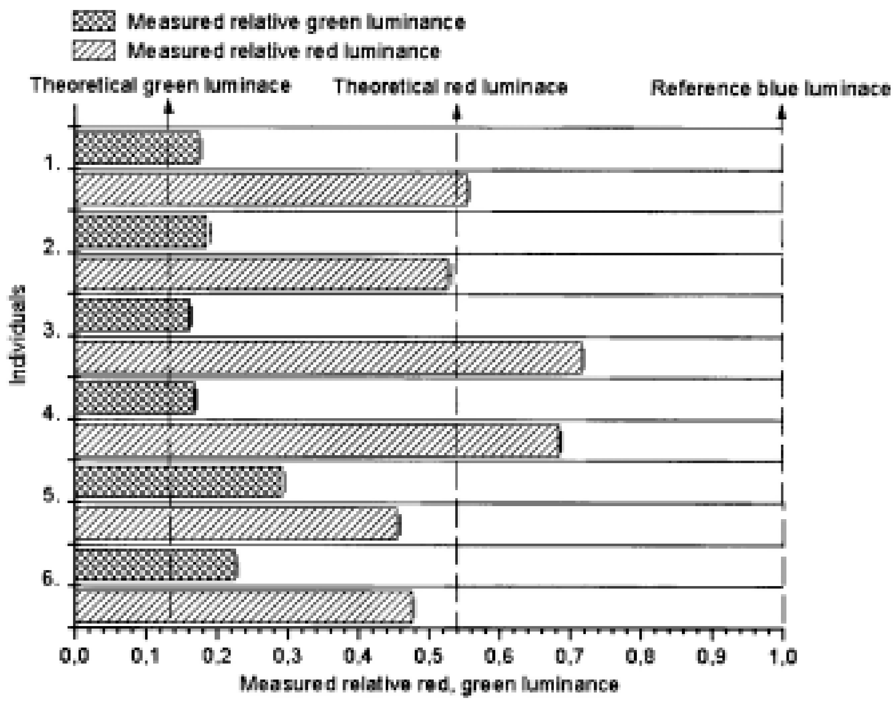

Fig. 1. Relative luminance ratios of monitor colors stimulating equal luminance sensation

3. Conclusion

In our paper we described a computer-controlled method suitable for identifying luminance sensation. Applying the method we have identified the relative luminance ratio of the monitor primary colors stimulating equal luminance sensations on six normal color vision people. We have also calculated the luminance sensations stimulated by the primary monitor colors using a theoretical method. The results of the theoretical calculations and the results of the actual measurements show only small difference. All participants of the experiment set the primary red and green a bit lighter than it was assumed from the theoretical calculations. We have shown that the additive mixture of the primary monitor colors stimulating equal luminance sensation results in a purple color. At the end we have drawn the readers attention to the finding that using computer-controlled color monitors it is feasible to create a color vision ability test based on individual relative luminance sensation compensation.

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