Colour Appearance Modelling for Self-luminous Colours

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ABSTRACT
An experimental setup and procedure for the evaluation of self-luminous colours viewed against both dark and luminous backgrounds is presented. Physical and visual data of self- luminous colours is gathered in order to develop a Colour Appearance Model for self-luminous colours under different viewing conditions. This model is needed for the evaluation of light sources.

Keywords
Colour appearance modeling; CAM; unrelated colours; colourfulness; perceptual attributes; appearance; self-luminous colours

1. INTRODUCTION
Colour Appearance Models (CAM) try to link the experimental measurable optical properties of stimuli and their corresponding perceptual attributes such as brightness, hue, colourfulness, lightness, chroma and saturation under varying conditions by taking into account some of the physiological processes taking place in the human visual system. Coloured stimuli can be categorized into related and unrelated colours. Related colours are colours perceived in relation to other colours, typically reflective colours and displays. Unrelated colours are seen in isolation from any other colours, like self-luminous colours (e.g. coloured light sources) surrounded by a dark background. Many CAMs have been proposed [1,2,3] for related colours. One of them, CIECAM02 [4], is widely accepted and has been successfully applied in printing and display technology to reproduce the colour appearance of images under different viewing conditions. However, no such general CAM is available for evaluating light sources. Although self-luminous unrelated colours viewed against a dark background can be modelled by CAM97u [5], the model does not apply for rather bright or luminous backgrounds. Nevertheless, this situation is frequently encountered, e.g. self-luminous LED panels and walls, traffic signals or advertisements viewed both by day and night. The aim of this research is to gather physical and visual data of self-luminous stimuli viewed against both dark and luminous background conditions. This will be done through optical measurements and observer assessments.. In this paper the experimental setup and procedures for this research will be described.

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Figure 1. Experimental room and modified wall

2. EXPERIMENTAL SETUP
An experimental room has been set up (see Figure 1 left). The room is 3 m x 5 m and has a gray ceiling. The walls are covered by black curtains and there is a black carpet on the floor. One wall (see Figure 1 right) has been modified for the experiments. It consists of a light-emitting homogeneous background (4 m wide, 3 m height) made of 40 fluorescent tubes mounted on a white wall behind a mobile diffusive panel. The luminance of the background can be adjusted by dimming of the fluorescent tubes. The correlated colour temperature (CCT) is 4000 Kelvin and can be modified by replacing the tubes. This background provides the adaptive field for the observer and exceeds a field of view of 70 degrees at a viewing distance of 211 cm. A small circular area, acting as the stimulus to be evaluated, is isolated from the self- luminous wall (see Figure 1 right). This circular stimulus has a diameter of 37cm, providing a 10 degree field of view for the observer. The stimulus is made of a LED-module placed in a cylindrical tube that is located immediately behind the diffusive panel. The R, G, B intensities of the LED-module are controlled by DMX (a digital communication network to control lighting etc.).
The spectral measurements of the stimuli take place with a telescopic measuring head coupled to a spectroradiometer with an optical fibre. A cooled CCD detector captures the signal at a predefined set of wavelengths between 350 nm and 900 nm. After a suitable calibration measurement with a spectral radiance standard, the spectral radiance can be calculated from the detected signal [6]. Spectral measurements of 58 carefully chosen stimuli, plotted in the $u'_{10}v'_{10}$ chromaticity diagram in Figure 2, were carried out in an attempt to cover the colour gamut as good as possible. All the stimuli have a luminance between 59 and 61 cd/m^2 (in later experiments, other luminance values will be chosen). During the first set of experiments a *dark (scotopic) viewing condition* has been investigated by covering the background with a black curtain. (see Figure 3).

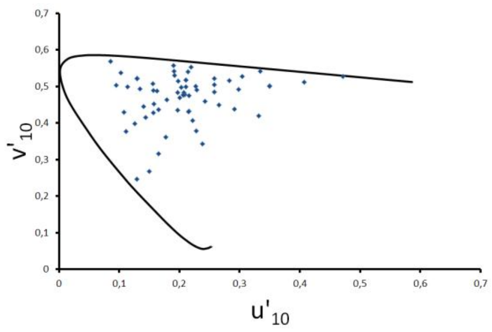

Figure 2. Chromaticity coordinates of the 58 stimuli plotted in the CIE $u'_{10}v'_{10}$ chromaticity diagram (L: 59-61 cd / m²)

Figure 3. Left: Experimental room with a dark background. Right: Example of a presented stimulus under dark viewing conditions.

3. EXPERIMENTAL PROCEDURES

In a series of psychophysical experiments, observers will evaluate the stimuli to obtain values for the perceptual attributes. The perceptual attributes for self-luminous colours are brightness, hue and colourfulness. However, colourfulness is difficult to evaluate without a huge time consuming training because it is not a term people are familiar with. From preliminary experiments it turned out that less training is necessary and answering is easier when people are asked to give a percentage of the amount of white against the amount of non-white they see in a self-luminous stimuli. The perceptual attributes brightness and hue, along with the amount of white, will be evaluated using the magnitude estimation method [4,7,8]. This method is designed to discover functional relationships between the physical properties of a presented stimulus and its perceptual attributes [9].

Prior to the actual experiments, the observers will first be allowed to adapt to the dark viewing conditions and to get familiar with the magnitude estimation method by presenting a small set of training stimuli. To keep a constant adaptation state, the observers will be shown each stimulus for a fixed amount of time before they will be asked to estimate its brightness relative to a reference achromatic stimulus. To this reference, appearing just before and after each stimulus, a fixed brightness value of 50 will be attributed. In the second part of the psychophysical experiment the stimuli will be shown again for the same amount of time as in the first experiment and observers will be asked to assign a percentage white versus non-white to the stimulus and to identify the unique hues they recognize in the stimulus as well as their relative proportions. An example of the questionnaire is given below:

<u>Brightness</u>

You will see 58 test stimuli. Each test stimulus is presented for the same amount of time. Afterwards, a reference stimulus will be shown. Give a value of the brightness of the test stimulus in comparison to the reference. The reference has a brightness of 50. A value of zero represents a dark stimulus without any brightness. There is no upper limit to the value of brightness.

<u>Percentage white and hue</u>

How much white against non-white do you recognize in the stimulus? Give a percentage of the amount of white.

Do you see blue in the stimulus?

Do you see green in the stimulus?

Do you see red in the stimulus?

Do you see yellow in the stimulus?

When you see two hues, give a percentage of the most dominant hue.

4. DATA COLLECTION

The perceptual attributes brightness and hue, evaluated by the observers, will be compared with the output of CAM97u in order to validate the questionnaire/experimental procedure. A relationship between colourfulness predicted by the model and the experimental values *percentage white* will be investigated. In the next step, the research will be extented by using brightness, hue and percentage white as perceptual attribute for self-luminous stimuli surrounded by a luminous background.

5. ACKNOWLEDGMENTS

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