MESOPIC LUMINOUS EFFICIENCY FUNCTIONS: EFFECT OF THE SIZE AND SHAPE OF THE VISUAL TARGET

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ABSTRACT

We investigated mesopic visual performance by using different stimuli as visual targets. The parameters of these visual stimuli influenced the results of the experiment. The objective of this work was to point out how the spectral sensitivity of the visual system depends on the size and on the shape of the visual targets at mesopic light levels in detection and recognition tasks. The aim is to contribute to the development of a visual performance based system of mesopic photometry.

Keywords: mesopic visual performance, stimulus size, stimulus shape

1. INTRODUCTION

Visual performance in the mesopic luminance range (between photopic and scotopic) has not yet been properly described. Several visual experiments were carried out to investigate the mesopic spectral sensitivity of the human eye[1,2]. One of these methods is the method of achromatic incremental contrast threshold which is based on the minimal visible contrast between visual targets and their background[3]. “Achromatic” means that the observer has to concentrate on detecting or recognizing the target and ignore its colour. “*Incremental*” means that the light of the visual target is *added* (superimposed) to its background. The objective of this work is to investigate how the spectral sensitivity of the visual system depends on the size and the shape of the visual target at mesopic light levels in these detection or recognition tasks, in order to contribute to the development of a visual performance based system of mesopic photometry[4].

2. METHOD

2.1. Stimuli

The experiment was carried out at a background luminance level of 0.1 cd/m^2. The background was a uniform square of about 70º of visual angle set to approximately CIE standard illuminant “A” chromaticity. It was projected by a slide projector filtered by neutral density filters. The light of the visual target was *superimposed* to the background by the aid of an LCD projector filtered by neutral density filters and quasi-monochromatic interference (QMI) filters. 24 QMI filters with 10 nm bandwidth were used in 10 nm steps from 440 nm to 680 nm to cover the visible spectrum. The luminance of the visual target was controlled by an 8 bit number. This number will be referred to as DAC value. The measurements were made by a PhotoResearch SpectraScan PR-705 spectro-radiometer.

The visual targets were *filled uniform discs* of 2°and 0.4° diameter (to investigate the effect of target size) and *Landolt* C *rings* of 2° diameter (to investigate the effect of target shape). The opening of the Landolt C ring was 0.4° diameter. The targets were always shown 20° off the visual axis of the observers (see Table 1).

Table 1. Parameters of the visual targets used in the experiment

Type of object	Landolt C ring	Disc
Eccentricity	20° off-axis	
Size	2°	2° and 0.4°
Background luminance	0.1 cd/m2	
Central wavelength	440 nm – 680 nm (25 QMI filters)	

2.2. Procedure and observers

After 20 minutes of adaptation time, visual targets were displayed for the observer. Each target was shown for 100 ms and hidden for 500 ms, and this was repeated with increasing DAC values. As soon as the observer could detect (disc) or recognize (Landolt C) a target, he/she pressed a button indicating his/her visual threshold. Recognizing in the Landolt C case means that the observer is able to tell clearly where the opening of the Landolt C ring is. For every visual threshold, the spectra of the background and the target were measured by the spectro-radiometer. This was done for each of the 25 investigated wavelengths and for every observer. The reciprocal values of the power differences between target and background defined the spectral sensitivity function of the observer. These functions were normalized to yield 1 at their maxima. Five young observers took part in the experiment, two males and three females with good colour vision. Colour vision was tested by the Farnsworth – Munsell 100 Hue test.

3. RESULTS AND DISCUSSION

Figure 1 shows a comparison of the three spectral sensitivity curves. The curves shown in Figure 1 represent average normalized sensitivity values (average of our 5 observers) together with 95% confidence intervals that show inter-observer variability. As can be seen from Figure 1, all spectral sensitivity functions are different from both the V(λ) and the V’(λ) functions. This difference is not only the shift of their maxima but also the appearance of very characteristic “chromatic” peaks well known from literature[5]. We can see certain similarities among the three mesopic sensitivity curves designated by 2º O, 0.4 º O, and 2º C in Figure 1. Every curve has one peak in the range of 510-530 nm and a second common peak at about 580 nm. The curves somewhat resemble the scotopic luminous efficiency function apart from the peak at 580 nm. Although the number of cones is less in the periphery and the light level is mesopic, cones seem to contribute to human vision in these conditions.

A further analysis of Figure 1 shows that the 2° disc curve shifts toward short wavelengths related to the 2° C curve.

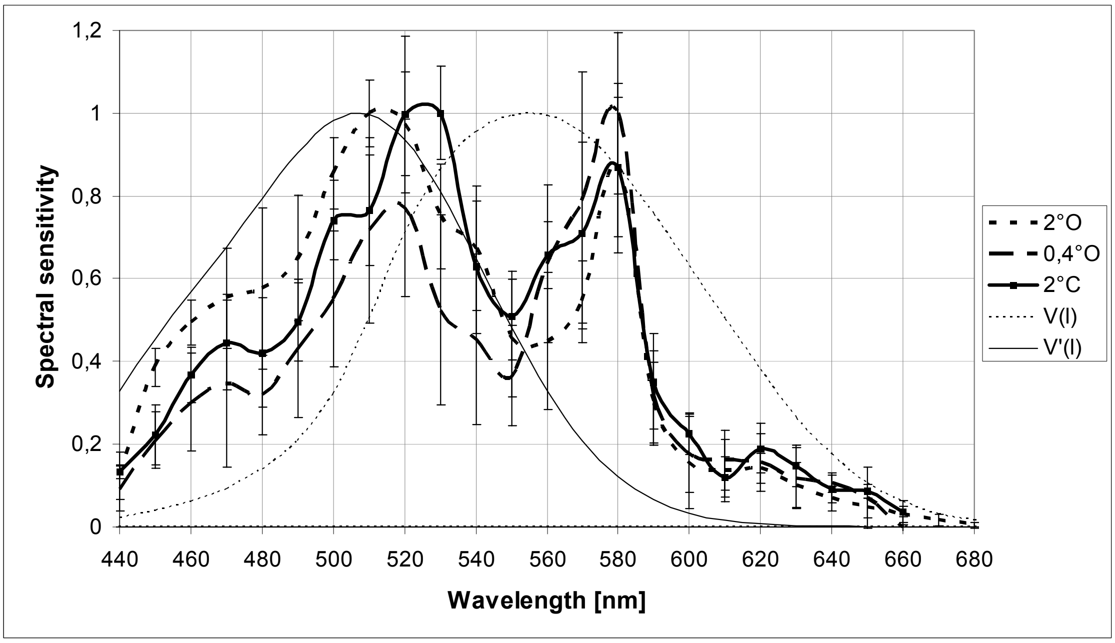

Figure 1 Normalized relative spectral sensitivity curves of the three visual targets, O: disc target, detection task; C: Landolt C target, recognition task. V(λ) and V’(λ) are also depicted.

To recognize the gap of the Landolt C, observers may also need their L and M cones and the spectral sensitivity of these is higher at longer wavelengths. For the 0.4 ° disc curve and for the 2° C curve, a minor maximum at 470 nm appeared, probably due to S-cone contribution. But for the 2° disc curve, this minor peak in the short wavelength range cannot be detected.

The multi-peaked shape of the spectral sensitivity functions in Figure 1 demonstrate the expected influence of the chromatic (opponent) system in the “achromatic incremental contrast threshold” method although the curves seem to be dominated by rod sensitivity.

Paired-sample T-tests were carried out for each wavelength separately, for each pair of the three kinds of visual targets (2º O, 0.4 º O, and 2º C). Significance is shown in Figures 2-4. In these significance Figures, black columns indicate values below the 5% significance level.

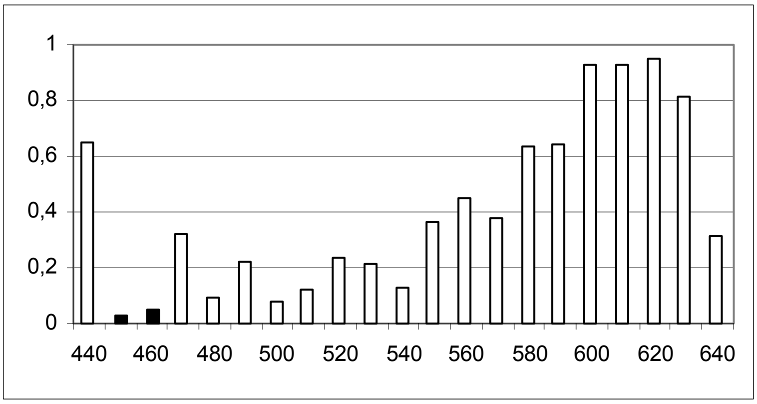

Figure 2 T-test: 0.4° disc and 2° disc. Black columns indicate values below the 5% significance level. Significance is on the ordinate and wavelength (nm) on the abscissa.

As can be seen from Figure 2, a significant difference between the 0.4° disc and 2° disc appears for 450nm and 460nm indicating the effect of visual target *size* in the short wavelength range.

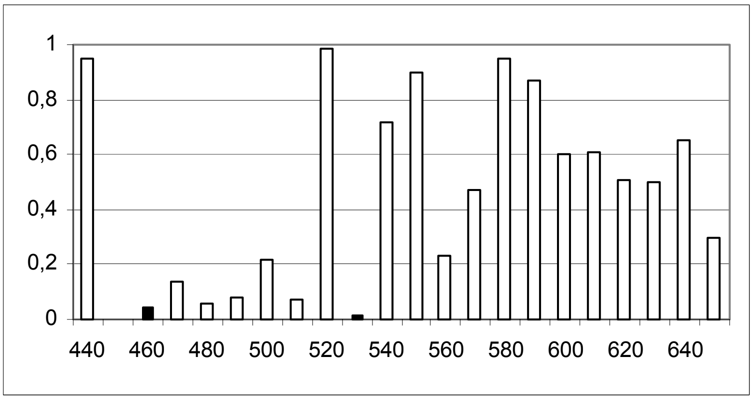

Figure 3. T-test: 2° C and 2° disc. Black columns indicate values below the 5% significance level. Significance is on the ordinate and wavelength (nm) on the abscissa.

As can be seen from Figure 3, a significant difference between the 2° C and 2° disc appears for 450nm-460nm and also for 530nm indicating the effect of visual target *shape* and the effect of visual task difference in the short wavelength range and in the range of the first (major) peak of the sensitivity curves.

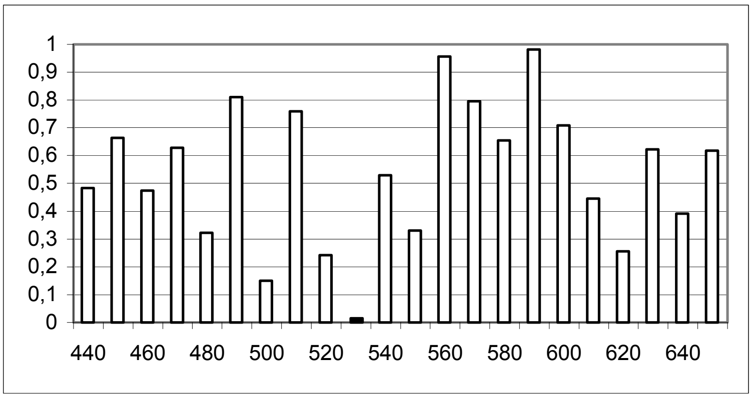

Figure 4 T-test: 2° C and 0.4° disc. The black column at 530nm indicates a value below the 5% significance level. Significance is on the ordinate and wavelength (nm) on the abscissa.

As can be seen from Figure 4, a significant difference between the 2° C and 0.4° disc appears for 530nm indicating the effect of visual target *shape and size* and the effect of visual task difference in the range of the first (major) peak of the sensitivity curves.

4. CONCLUSION

The incremental achromatic detection and recognition contrast threshold method was used to investigate the spectral sensitivity curves to study mesopic visual performance. Results exhibited three, more or less explicit peaks. In general, the contribution of the colour-opponent system was obvious in all three spectral sensitivity functions. The chromatic contribution to mesopic spectral sensitivity may be practically relevant and it may be important to consider this in modelling mesopic spectral luminous efficiency.

We found significant differences among the spectral sensitivity functions of the three different kinds of visual stimuli (2º disc, 2º Landolt C, and 0.4º disc). This corroborated the significant effect of target size and target shape on mesopic spectral sensitivity functions.

5. REFERENCES

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