Measuring mesopic visual performance: Reaction time measurements – effect of retinal eccentricity

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ABSTRACT

Human performance under mesopic (twilight) conditions is of major interest to optimize street lighting and provide adequate illumination to avoid dangerous traffic situations. In the mesopic region, between 3 cd/m^2 and 10^{-3} cd/m^2 we loose gradually our colour vision and visual acuity becomes poorer and poorer [1]. Mesopic photometry is important in night-time traffic situations where street lighting produces mesopic vision. Until now, no official system of mesopic photometry has been recommended but a review has been published[2].

The reaction time method was chosen for our visual experiment. Both electrophysiological studies and psychophysical studies showed that reaction times give rise to spectral sensitivity function resembling V(λ) and V'(λ), at photopic and scotopic levels, respectively.

Video clips were recorded from inside of a moving car, and virtual bouncing balls were embedded into the digital video files. The subject had to operate a switch when he/she noticed the object (i.e. the bouncing ball). The driver's reaction times were measured for obstacles of the three basic colours of a data projector, for five background luminance values, and different photopic contrasts between the ball and its background. The bouncing balls appeared in three different ranges of retinal eccentricity.

Reaction time values as a function of photopic contrast between the ball and its background were significantly influenced by colour, background luminance, and the degree of retinal eccentricity.

Keywords: reaction time, mesopic vision, visual performance, retinal eccentricity

1. INTRODUCTION

A series of simulated night-driving experiments were carried out at the Laboratory of Colour and Multimedia of the University of Veszprém, in Hungary. A simple visual target (a 2º plain disc) was used and the uniform background was replaced by a projected video sequence, thus taking a step toward virtual reality. Observers were immersed in the scene and the driving simulator delivered the sensation of presence to the observers, and motivated them to fulfil their visual task with full attention. During the photometric characterization, the spectral distributions of the background and the visual target were measured for each experimental situation.

2. EXPERIMENTAL METHOD

The reaction time method was chosen for the visual criterion of the night-time driving experiment to consider the importance of avoiding accidents in real life situations. The reaction-time method does have its drawbacks: data tend to show considerable variability and long-term drifts in terms of absolute response times.

The night-driving simulator was constructed by embedding artificial objects into digital video files, see Figure 1. Projected videos showed a street from the viewpoint of the driver who drove at constant speed in the street. At different moments, a filled homogeneous disk representing a “bouncing ball” (see below) jumped around in front of the vehicle. Then, the “driver” had to operate a switch as soon as she noticed the target and the experimental software registered her his reaction time.

Figure 1. Screenshots from the videos: at given moments, coloured “balls” pop into the scene.

The video clips were originally recorded from inside of a moving car. The car went through the streets of the city of Veszprém (Hungary) by night, and a digital camera recorded the movies. The simulation took place in a dark room. The video clips were presented by an LCD projector. The observer sat in front of a white canvas. A crosshair placed in the middle of the canvas helped the subject to keep her fixation. Four young female observers participated in the experiment, and each subject repeated every observation 20 times. Each observer had normal colour vision.

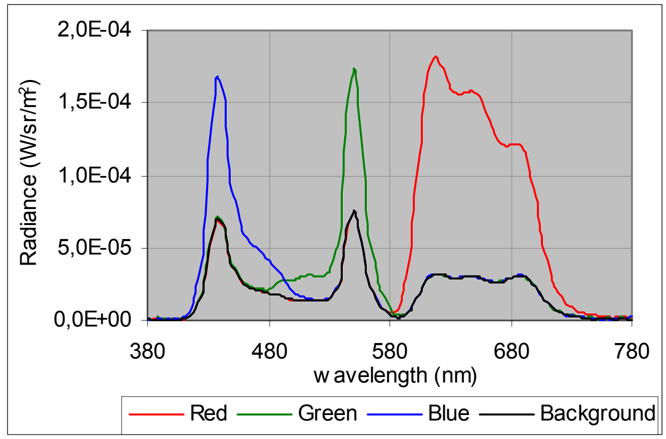
3. VISUAL STIMULI

Table 1 describes the visual targets used in the experiment. The driver’s reaction times were measured for obstacles in the three basic colours of the data projector (red, green, and blue), for 3 different eccentricities and for 5 different mesopic background luminance values.

An example of the typical spectral power distribution of the three visual targets representing the primary R,G,B channels of the LCD projector, and their background are shown in Figure 2.

Table 1. Description of the visual stimuli

Type:	2° plain disk (bouncing ball)
Colour:	red, green, blue
Photopic contrast domain:	0.025-0.350
Presentation time:	2 s
Eccentricity (3 cases):	11.3º-13.7º 15.7º-19.0º 32.7º-38.1º



4. RESULTS

Lower luminance values result in longer reaction times and larger variability (see Figure 3).

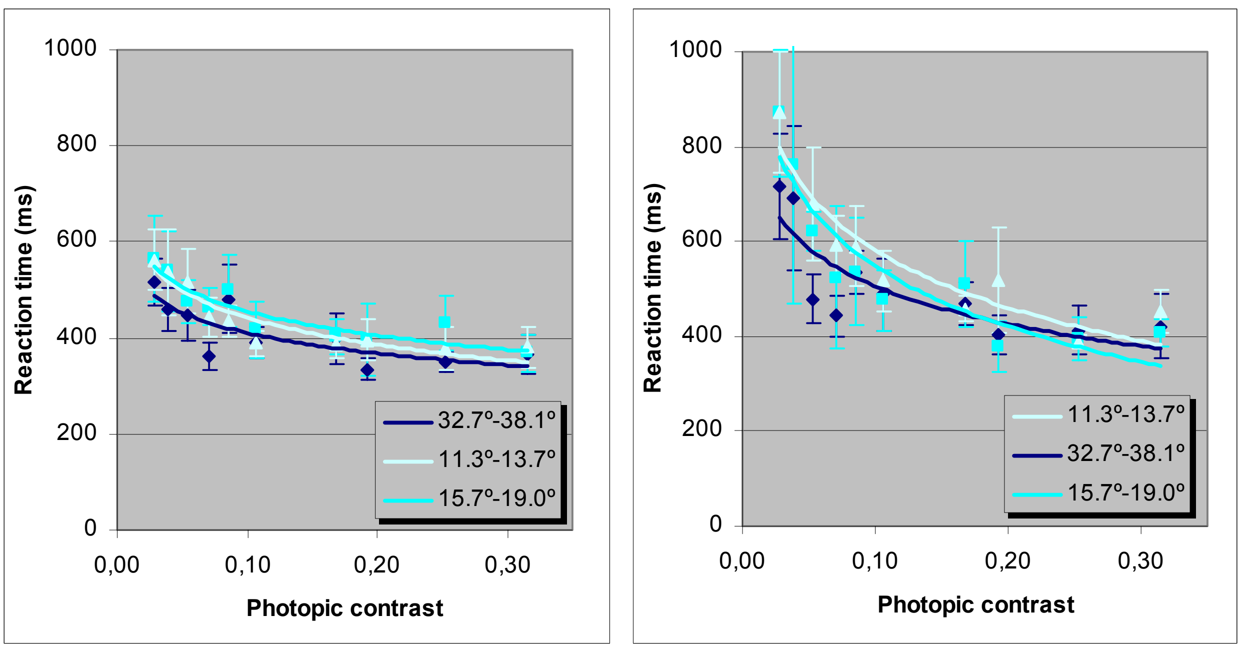
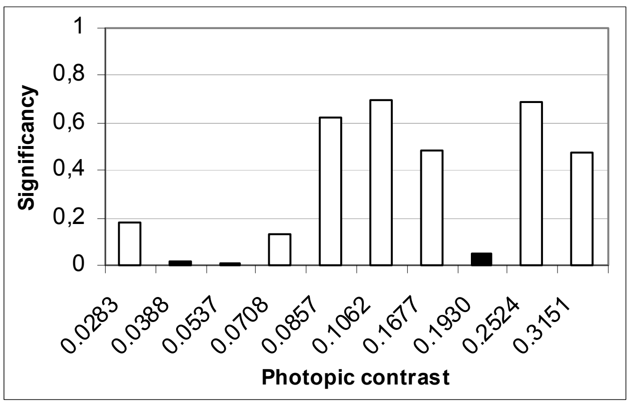


Figure 3. Observation of the blue targets at three different eccentricities. RT values and 95% confidential intervals at 1.85 cd/m^2 background luminance (on the left), and at 0.1 cd/m^2 background luminance (on the right).

ANOVA tests have been performed on the results. We found a significant dependence of reaction time on target colour, background luminance and retinal eccentricity.

Figure 4 shows an example for the ANOVA tests where background luminance level, target colour and photopic contrast were fixed variables. The dependence of RT on retinal eccentricity was analyzed. As can be seen from Figure 4, the effect of retinal eccentricity was significant in certain ranges of photopic contrast. If we compare the graph in the left of Figure 4 (blue targets at 0.1 cd/m2) with the graph on the right of Figure 3 (same condition), we can conclude that for blue targets, reaction time decreases with increasing eccentricity. The explanation for this finding may be peripheral rod vision which is more sensitive to shorter wavelengths.



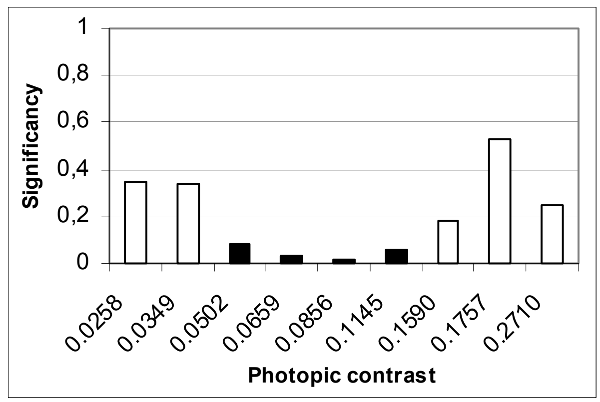


Figure 4. Example of the ANOVA tests. Left: blue targets at 0.1 cd/m^2 background luminance level; right: red targets at 0.3 cd/m^2 background luminance level. Black columns show a significant effect of eccentricity ($p<0.1$)

5. CONCLUSION

The investigation of the human visual system under mesopic (twilight) conditions is a very hard task since the accuracy of usual measuring instruments is lower in this luminance range and both the dark adaptation of observers and the measurements require a long time. In addition to this, mesopic visual tasks are hard for the observers as the rod and cone systems show complex interactions. These might be the reasons why there is no generally accepted system of mesopic photometry. The experiments presented in this work show that mesopic vision can be investigated effectively by the aid of Virtual Reality and such experiments are close to a practical situation.

Our results show that there are significant reaction time differences depending on colour, background luminance and eccentricity. Lower luminance values result in longer reaction times, and also the observation of red targets requires more reaction time than the blue and green ones. For blue targets, reaction time decreases with increasing retinal eccentricity showing that peripheral rod vision is more sensitive to shorter wavelengths.

References

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