Scotopic vs. Photopic

White Paper
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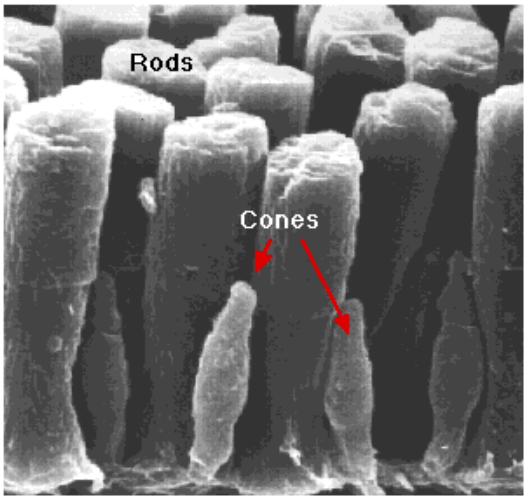
There is a confusing topic in the lighting industry that revolves around how to measure light and the correlation of that measurement to what the human eye actually sees or perceives. The most common terms in these vision and measurement conversations are Scotopic and Photopic.

In order to better understand these terms allow me to define parts of the eye that are the photoreceptors of light, color and space. They are considered part of the retina and are called Rods & Cones.

Rods are responsible for vision at low light levels (scotopic vision). They do not interpret color, and have low spatial acuity.



Cones are responsible for vision at higher light levels (photopic vision), are capable of excellent color interpretation and are responsible for high spatial acuity. The central fovea (retina) is populated exclusively by cones. Consequently humans see better in daylight than at night.

The light levels where both cones and rods are operational are called mesopic.

Scotopic vision is the vision of the eye under low light conditions. In the human eye scotopic vision is produced exclusively through rod cells. Scotopic vision occurs at luminance levels of 10^{-2} to 10^{-6} cd/m² (candela per square meter).

Photopic vision is the vision of the eye under well-lit conditions (luminance level 1 to 10^{6} cd/m²). In humans and many other animals, photopic vision allows color perception, and spatial acuity, interpreted by cone cells.

Mesopic vision occurs in intermediate lighting conditions (luminance level 10^{-2} to 1 cd/m²) and is effectively a combination of scotopic and photopic vision. This however gives inaccurate visual acuity and color discrimination, because the rods are still partially involved in sending information to the retina.

In normal light (luminance level 1 to 10^{6} cd/m²), vision is dominated by cone cells and is photopic vision. There is good visual acuity and color discrimination.

More about Cones

The human eye uses three types of cones to sense light in three respective bands of color. The biological pigments of the cones have maximum absorption values at wavelengths of about:

- 420 nm (blue)
- 534 nm (Bluish-Green)
- 564 nm (Yellowish-Green).

Their sensitivity ranges overlap to provide vision throughout the visible spectrum. The maximum efficacy is *683 lm/W at a wavelength of 555 nm (green)*. This someday will become the lighting standard!

Measurement

The traditional method of measuring light assumes photopic vision yet artificial light falls into mesopic vision, making the traditional measurements poor indicators of how a person sees at night.

Prior to 1951, there was no standard for scotopic photometry (light measurement); all measurements were based on the photopic spectral sensitivity function V(λ) which was defined in 1924. In 1951 the CIE (International Commission on Illumination) established the scotopic luminous efficiency function, V'(λ). However, there was still no system of mesopic photometry. This lack of a proper measurement system can lead to difficulties in relating light measurements under mesopic luminance levels to visibility. Due to this deficiency, the CIE established a special technical committee (TC 1-58) for collecting the results of mesopic visual performance research.

According to the Helsinki University of Technology the ability to test for mesopic photometry is still deficient. "The human spectral luminous efficiency functions are derived from psychophysical experiments, which measure spectral sensitivity with certain visual criteria and under defined set of conditions. The majority of the existing mesopic models are based on brightness matching. However, a link to visual tasks and the prediction of visual performance with the brightness based models is still deficient. It has recently been internationally acknowledged, that there should be more understanding of the factors that affect visual performance in the mesopic range and that these factors should be considered in new approaches of developing mesopic photometry."

As our knowledge increases our ability to reproduce natural light where the human eye best responds will also advance. With this upward mobility the technological advances in manufacturing LED lights also progresses. Currently the rapidly changing international lighting sector revolves around LEDs and their ever-promising advantages. These advances help companies like LED Industries manufacture better quality lights that will last longer and payback quicker and are now the standard for best-in-class luminaires that meet the needs of the mesopic demands, as we currently know them, from municipalities and commercial applications alike.