2.1.3 Physiology of the eye

The information presented in this chapter is based on the consideration that it is inadequate to portray the eye as an optical system when describing human perception. The process of perception is not a matter of how an image of our environment is transferred to the retina, but how the image is interpreted, how we differentiate between objects with constant properties in a changing environment. Although this means that priority will be given here to the process by which the image is created both physiologically and psychologically, the eye and its fundamental properties should not be ignored.

The eye is first and foremost an optical system creating images on the retina. We have described this system by comparing the eye with a camera, but more interesting by far is the surface on which the image occurs - the retina. It is in this layer that the pattern of luminances is translated into nervous impulses. The retina has, therefore, to possess light sensitive receptors that are numerously sufficient to allow a high resolution of the visual image.

On close examination it is evident that these receptors are not arranged in a uniform pattern; the retina is a very complicated structure: firstly there are two different types of receptor, the rods and the cones, which are not distributed evenly over the retina. At one point, the so-called "blind spot", there are no receptors at all, as this is the junction between the optic nerves and the retina. On the other hand there is an area called the fovea, which is at the focal point of the lens. Here there is the greatest concentration of cones, whereas the density of the cones reduces rapidly towards the peripheral area. This is where we find the greatest concentration of rods, which are not evident at all in the fovea.

The reason for this arrangement of different receptor types lies in the fact that our eyes consist of two visual systems. The older of these two systems, from an evolutionary point of view, is the one involving the rods. The special features of this system are a high level of light-sensitivity and a large capacity for perceiving movement over the entire field of vision. On the other hand, rods do not allow us to perceive colour; contours are not sharp, and it is not possible to concentrate on objects, i.e. to study items clearly when they are in the centre of our field of vision.

The rod system is extremely sensitive and it is activated when the illumance level is below 1 lux. The main features of night vision - mainly the fact that colour is not evident, contours are blurred and poorly lit items in our peripheral field of vision are more visible – can be explained by the properties of the rod system.

The other type of receptors, the cones, make up a system with very different properties. This is a system which we require to see things under greater luminous intensities, i.e. under daylight or electric light. The cone system has a lower level of light-sensitivity and is concentrated in the central area around the fovea. It allows us to see colours and sharper contours of objects on which we focus, i.e. whose image falls in the fovea area.

In contrast to rod vision, we do not perceive the entire field of vision uniformly; the main area of perception is in the central area. The peripheral field of vision is also significant, however; if interesting phenomena are perceived in that area then our attention is automatically drawn to these points, which are then received as an image in the fovea to be examined more closely. Apart from noticing sudden movement, striking colours and patterns, the main reason for us to change our direction of view is the presence of high luminances - our eyes and attention are attracted by bright light.

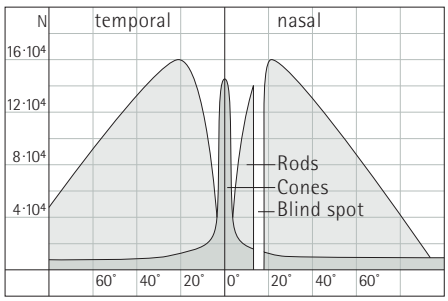
One of the most remarkable properties of the eye is its ability to adapt to different lighting conditions. We can perceive the world around us by moonlight or sunlight, although there is a difference of a factor of 10^5 in the illuminance. The extent of tasks the eye is capable of performing is extremely wide - a faintly glowing star in the night's sky can be perceived, although it only produces an illuminance of 10^{-12} lux on the eye.

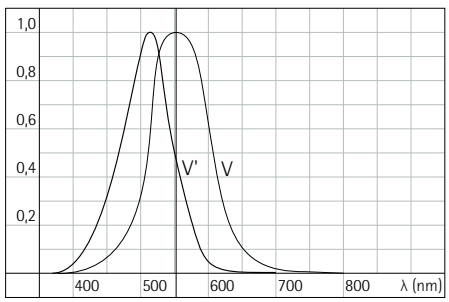
This accomodation is only influenced to a very small extent by the pupil, which regulates incident light in a 1:16 ratio. Adaptation is performed to a large extent by the retina. The rod and cone system handles different levels of light intensity. The rod system comes into effect in relation to night vision (scotopic vision), the cones allow us to see during the daytime (photopic vision) and both receptor systems are activated in the transition times of dawn and dusk (mesopic vision).

Although vision is therefore possible over an extremely wide area of luminances there are clearly strict limits with regard to contrast perception in each individual lighting situation. The reason for this lies in the fact that the eye cannot cover the entire range of possible luminances at one and the same time, but adapts to cover one narrow range in which differentiated perception is possible. Objects that possess too high a luminance for a particular level of adaptation cause glare, that is to say, they appear to be extremely bright. Objects of low luminance, on the other hand, appear to be too dark.

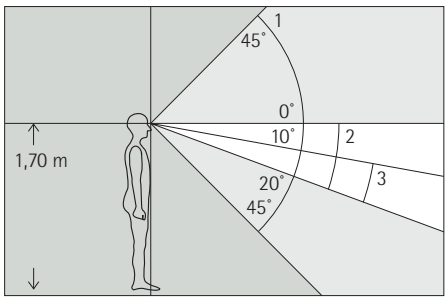
The eye is able to adjust to new luminance conditions, but as it does so it

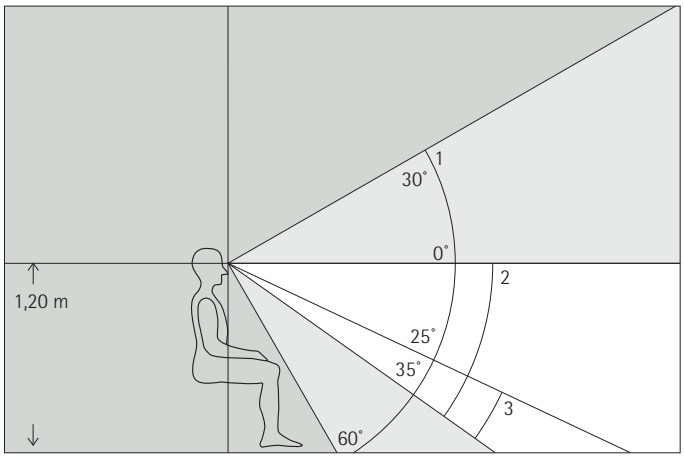
Number N of rods and cones on the retina in relation to the angle of sight.



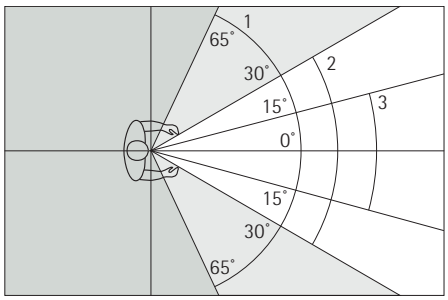


Relative spectral luminous efficiency of rods V' and cones V.

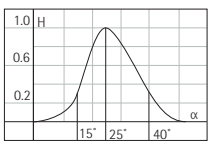


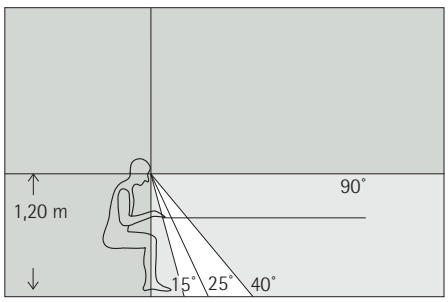


Visual field (1), preferred visual field (2) and optimum field of vision (3) of a person standing (above) and sitting (centre, below) for vertical visual tasks.



Frequency H of angle of sight α for horizontal visual tasks. Preferred field of vision between 15° and 40°, preferred direction of view 25°.





Preferred field of vision for horizontal visual tasks. Preferred direction of view 25°.

simply selects a different but restricted range. This process of adaptation does take time. Adapting from dark to light situations occurs relatively rapidly, whereas adapting from light to darkness requires a considerably longer time. A good example of this is how bright we find it outside having come out of a dark cinema auditorium during the daytime, or the transitory period of night blindness we experience when entering a very dark room. Both the fact that contrast in luminance can only be processed by the eye within a certain range, plus the fact that it takes time to adapt to a new level of lighting, or brightness, have an impact on lighting design: the purposeful planning of different luminance grades within a space, for example, or when adjusting lighting levels in adjacent spaces.

2.1.4 Objects of perception

Although this chapter has described the psychological mechanisms involved in the perception process together with the physiological prerequisites, a third area has only been touched upon - the subject of perception. To this point the things that were seen were either "objects" or "figures" in general or examples chosen to illustrate a certain mechanism. We do not perceive any object that comes within our field of vision, however. The way the fovea prefers to focus on small, changing scenes shows that the perception process purposefully selects specific areas. This selection is inevitable, as the brain is not capable of processing all the visual information in the field of vision, and it also makes sense because not all the information that exists in our environment is necessarily relevant for perception.

Any attempt to describe visual perception effectively must therefore also take into account the criteria by which the selection of the perceived information is effected. In the first instance the value of any particular information relates to the current activity of the observer. This activity may be work or movement-related or any other activity for which visual information is required.

The specific information received depends on the type of activity. A car driver has to concentrate on different visual tasks than a pedestrian. A precision mechanic processes different information than a worker in a warehouse. A visual task can be defined by size or location; it is of importance whether a visual task is movement-related or not, whether small details or slight contrasts have to be registered, whether colours or surface structures are essential properties. Lighting conditions under which the visual task can be perceived to an optimum degree can be determined from the above-mentioned specific features. It is possible