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2.1.2 Accommodation

It is not well known that most of the refraction of incident light rays (about 70%) occurs at the cornea (including the effect of the thin film of tears on it). The cornea has a shape of a converging lens and a refractive index of 1.38. Practically, both the cornea and lens (the cornea-lens system) are responsible for the production of the image of an observed object on the retina. The focal length of the cornea-lens system approximately equals 18 mm. Deviations from this value, amounting up to ±1 mm, are caused by the contraction (or relaxation) of the ciliary muscle, which results in an increase (or decrease) of the lens curvature. (IESNA 2000; Goldstein 2014)

The lens equation provides the well-known relationship between the object distance (D_o), the image distance (D_i) and the focal length (f) of the eye optical system:

$$\frac{1}{D_o} + \frac{1}{D_i} = \frac{1}{f}. \tag{2.1}$$

It shows that the adjustment of the focal length enables the same image distance (the constant position of the image on the retina) for various object distances.

The ability of the eye to adjust its focal length (to refocus), appropriately focusing images of objects which are both close and distant, is called accommodation. However, full accommodation is only possible if the object distance is longer than approximately 20 cm, representing the minimum distance of clear vision of a normal eye. (Dimic and Virag 1972)

The accommodation ability weakens with age, which is why many persons from their forties on cannot clearly see objects at usual short distances (for example, reading a book). Spectacles serve to change the effective focal length in such cases, restoring sharp images. (Philips Lighting 1993)

2.1.3 Depth perception

The brain estimates the size and distance of an object by means of the size and shape of its slightly different images created on the retinal surfaces of both eyes. It is believed that both images are two-dimensional, as well as that their slight differences (caused due to the eyes' different position on the head) provide sufficient information to the brain to calculate depth in the scene (the so-called depth perception). The ability to evaluate depth, which represents a precious property of normal binocular vision, is also known as stereopsis (three-dimensional sight) (Blake and Seculer 2006).

The fact that depth perception also exists when a scene is viewed with only one eye is more difficult to explain. The only explanation which seems to make sense is that our present knowledge and past experience of the luminous environment are engaged in the process of perception.

The linear perspective should also be mentioned. It is well known that we gain an impression that parallel lines converge toward a single distant point, which is based on the fact that the viewing angle decreases when the object distance from the observer increases (for example, the nearly parallel river banks produce an impression of getting closer to each other as the distance increases). Note that Renaissance artists were the first to apply this phenomenon on a two-dimensional canvas.

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2.2 Visual perfomance (capabilities of the visual system)

In order to see an object, it has to be of a size which can be perceived from the considered distance. In addition, either a sufficient luminance contrast or colour contrast should exist. In order to evaluate the fulfillment of these conditions (except the one related to colour difference), visual actuity, luminance contrast and luminance contrast sensitivity have been defined.

2.2.1 Visual acuity (sharpness of vision)

An object is seen sharply if the eye is capable to distinguish its very close lines. The measure of visual acuity is the reciprocal of the minimum angle (expressed in minutes of arc) formed by the eye and two closest lines which the eye can distinguish (in **Fig. 2.2** this angle is designated with θ_{min}) (Philips Lighting 1993). According to **Fig. 2.2**,

$$\theta_{min} = \frac{d}{s_{max}}[\mathrm{rad}] = \frac{d}{s_{max}} \cdot \frac{180}{\pi} \cdot 60 \qquad (2.2)$$

(s_{max} is the maximum distance of the observer from the so-called Landolt broken ring at which the lines of the gap (at distance d) are just distinguished as being separate).

Visual accuity is determined under the condition that the considered neighbouring lines are resolved on 50% of the occasions the target is presented (Boyce 2014).

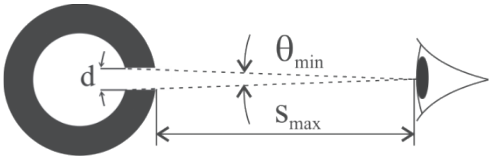

Figure 2.2 The minimum angle

Visual acuity increases with the illuminance level. However, at levels exceeding 100 lx it has approximately the constant value of 1, which is therefore considered the visual acuity of a normal eye (the corresponding minimum angle equals 1 minute) (Dimic and Virag 1972). Note that visual acuity increases when light spectrum becomes narrower (for example, visual acuity is significantly higher when low-pressure sodium lamps, emitting almost monochromatic light, are used than when metal-halide lamps are applied).

Visual acuity is maximal for the images formed in the fovea, decreasing with the increase of the angle between the object direction and the eye axis.

It was noticed that some African tribe natives were able to spot animals on significantly more distant locations than civilised persons could. However, well organized tests showed that they did not possess better sight (higher visual acuity) than the representatives of the civilised population. An explanation of their improved ability to spot distant animals possibly lies in the fact that, living in nature and being constantly endangered by wild animals, they have become trained to spot them at distances where other people cannot. (Le Grand 1957)

This confirms that the final (psychological) phase of the process of vision is very important in our visual experience of the world.

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