INTERNATIONAL STANDARD

ISO 8995

First edition
1989-10-01

Principles of visual ergonomics — The lighting of indoor work systems

Principes d'ergonomie visuelle — L'éclairage des systèmes de travail intérieurs

Reference number
ISO 8995 : 1989 (E)

Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8995 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, in collaboration with the International Commission on Illumination (CIE).

This page intentionally left blank

Principles of visual ergonomics — The lighting of indoor work systems

0 Introduction

The aim of visual ergonomics is

— to optimize the perception of visual information used during the course of work;

— to maintain an appropriate level of performance;

— to guarantee maximum safety;

— to provide acceptable visual comfort.

These objectives are achieved in practice by designing the visual environment to take account of a person's capabilities.

Figure 1 shows the parameters that influence a worker's performance in a given visual environment. Parameters such as perceptual ability and the characteristics of the task[1] to be completed determine the quality of the operator's visual skills. Lighting and work space factors provide the more "environmental" determinants of visual performance. All influence the nature of the visual information available and hence the worker's consequent levels of task performance. Consequently, it may be possible to compensate for a defect in one of the factors by an enhancement of one or more of the others. For example it may be possible to provide adequate visual information by improving the contrast of the task attributes and other task or operator variables, yet have lower overall illumination levels if there is a limit to the illuminance which can be provided.

Considerations such as these imply that the application of visual ergonomics may increase the number of design options available. Consequently, visual ergonomics can be used to provide a range of options, from general guidelines to more detailed information concerning a parameter that needs to be modified to provide an acceptable visual environment.

The ranges of glare limitation (see annex A) and recommended illuminances (see annex B) are taken from existing national standards, codes and regulations. They are intended as examples and guidance for designing the visual environment of work systems especially in those cases where no national codes or legal rules exist.

1) Task is also taken to mean task attributes.

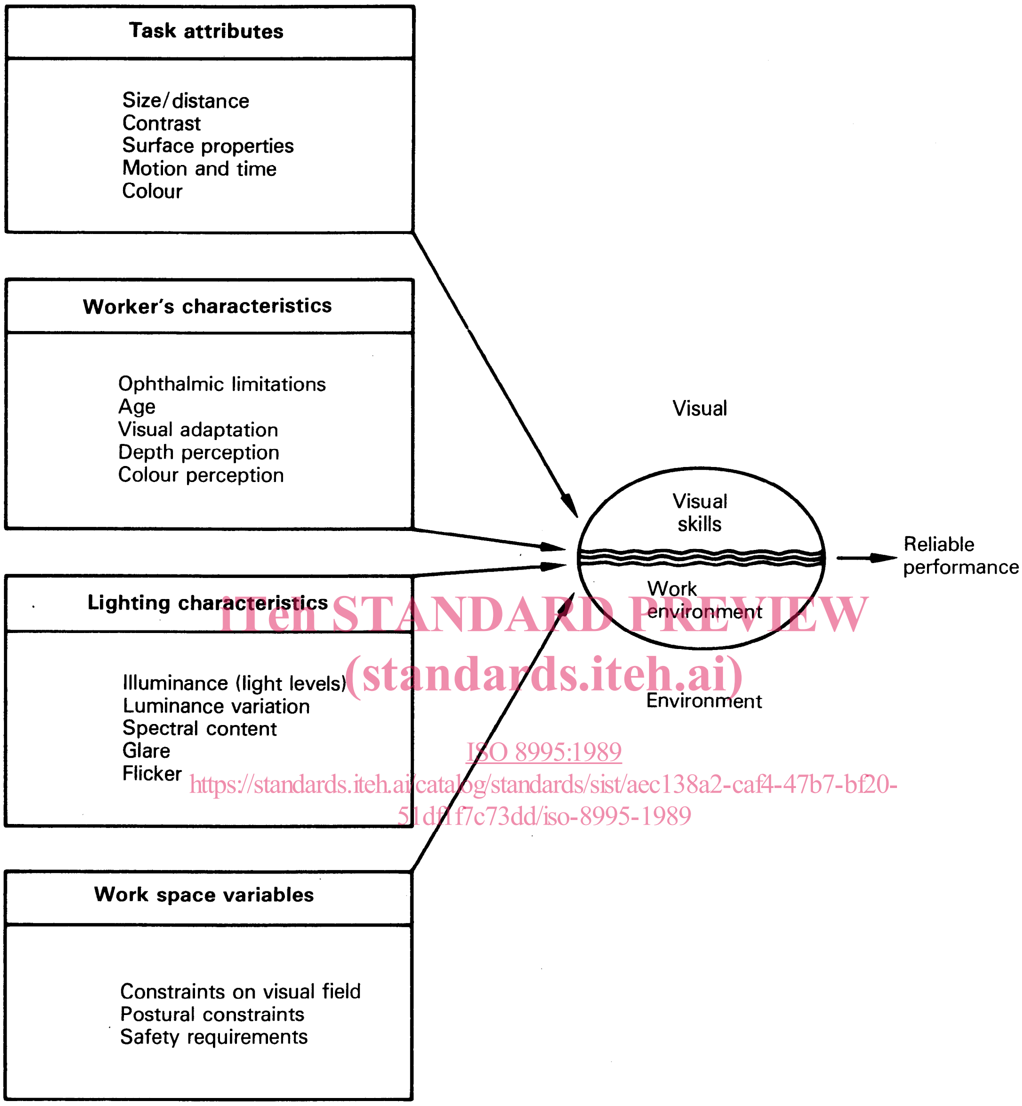


Figure 1 — Major parameters influencing a worker's performance in the visual environment

1 Scope and field of application

This International Standard lays down the principles of visual ergonomics and identifies the parameters that influence visual performance. It also presents the criteria that have to be satisfied in order to achieve an acceptable visual environment.

This International Standard is applicable to working areas in industrial buildings, offices and hospitals, etc., but not those working areas of low luminance used for such activities as, for example, projection, viewing of transparencies, handling of photosensitive materials. The special requirements specified for interiors where visual display units are used are also beyond the scope of this International Standard. Similarly, visual tasks requiring special analysis such as where optical aids are used, to enhance task detail, are also not covered.

This International Standard is intended primarily for the non-specialist involved in matters concerned with the visual environment. The references in clause 2 provide more detailed information to complement this International Standard.

It is recommended that a specialist be consulted if the information provided in this International Standard is not readily applicable, or if a more precise evaluation is needed because technical difficulties and cost constraints limit the role played by lighting.

2 References

ISO 6385, *Ergonomic principles in the design of work systems.*

CIE Publication No. 13.2, *Method of measuring and specifying colour rendering properties of light sources.*

CIE Publication No. 16, *Daylight — International recommendations for the calculation of natural daylight.*

CIE Publication No. 17, *International lighting vocabulary.*

CIE Publication No. 19/2, *An analytic model for describing the influence of lighting parameters upon visual performance.*

CIE Publication No. 29/2, *Guide on interior lighting.*

CIE Publication No. 55, *Discomfort glare in the interior working environment.*

3 Definitions

For the purposes of this International Standard, the definitions in CIE Publication No. 17 and the following definitions apply.

3.1 Eye and vision

3.1.1 adaptation: The process which takes place as the eye adjusts to the luminance and/or the colour of the visual field or the final state of this process.

3.1.2 accommodation: Adjustment of the focus of the eye, normally spontaneous, for the purpose of attaining maximum visual acuity at various distances.

3.1.3 visual acuity: The capacity for discriminating details in objects or between objects which are very close together.

Quantitatively, it can be expressed by the reciprocal of the angle subtended by the extremities of the detail separation which is just visible at the entrance of the pupil or other point of reference on the eye.

3.1.4 contrast: A term that is used subjectively and objectively.

a) Subjective sense: Subjective assessment of the difference in appearance of two parts of a field of view seen simultaneously or successively. (Hence: brightness contrast, colour contrast, simultaneous contrast, successive contrast.)

b) Objective sense: Quantities usually defined as a luminance ratio (usually for successive contrasts) L_2/L_1, or by the following formula (for surfaces viewed simultaneously):

$$\frac{L_2 - L_1}{L_1}$$

where

L_1 is the dominant or background luminance;

L_2 is the object luminance.

When the areas of different luminance are comparable in size and it is desirable to take an average, the following formula may be used instead:

$$\frac{L_2 - L_1}{0,5\,(L_2 + L_1)}$$

3.1.5 brightness: Attribute of the visual sensation associated with the amount of light emitted from a given area.

It is the subjective correlate of luminance.

3.1.6 glare: The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the brightness of the general surroundings to which the eyes are adapted.

3.1.7 reflected glare: Glare resulting from specular reflections from polished or glossy surfaces.

3.1.8 flicker: Visual impression of intermittency, alternation, or variation in presentation of light.

3.1.9 stroboscopic effect: Apparent immobilization or change of motion of an object, when the object is illuminated by a light of appropriate frequency and varying intensity.

3.1.10 visual field: The area or extent of physical space visible to an eye in a given position.

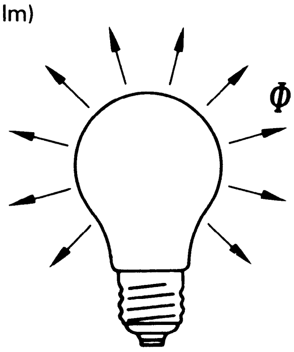
3.1.11 visual environment: The total space which can be seen from a particular location by moving one's head and eyes.

3.2 Quantities and units of light and colour

3.2.1 luminous flux: The light power emitted by a source, or received by a surface. The quantity is derived from radiant flux (power) by evaluating the radiation in accordance with a standardized spectral sensitivity of the eye.

Symbol: Φ

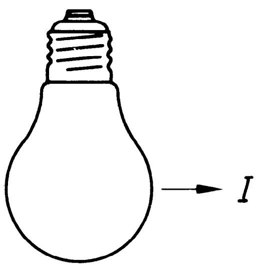
Unit: lumen (lm)



3.2.2 luminous intensity (of a source in a given direction): The luminous flux per unit solid angle in a specific direction. It is the luminous flux on a small surface normal to the direction, divided by the solid angle that the surface subtends at source.

Symbol: I

Unit: candela (cd)

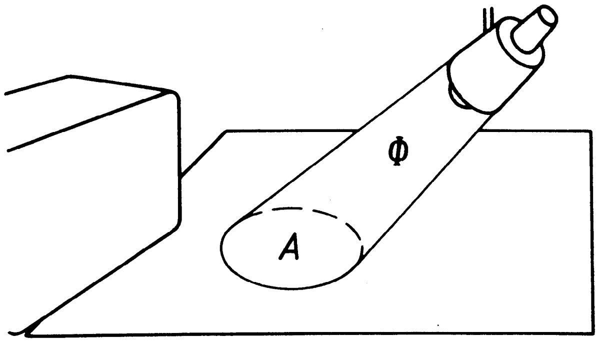


3.2.3 illuminance: The density of the luminous flux (Φ) incident at a point. In practice the average illuminance of a given surface is calculated by dividing the flux falling on it by the area (A) of the illuminated surface.

Symbol: E

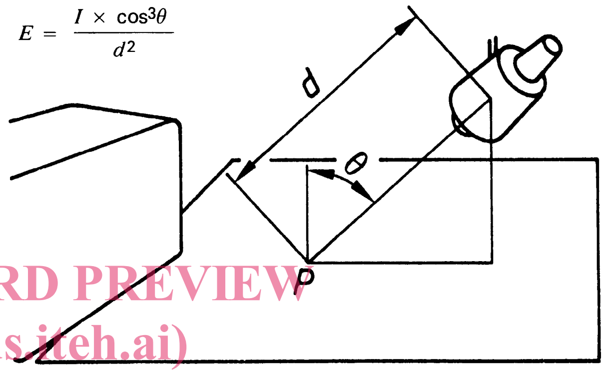
$$E = \frac{\Phi}{A}$$

Unit: lux (lx) (1 lx = 1 lm/m²)



NOTE — The illuminance at a specified point P at a given distance d from the source of intensity I in that direction and at an angle of incidence θ is calculated using the formula

$$E = \frac{I \times \cos^3\theta}{d^2}$$



3.2.4 luminance: The physical measurement of the stimulus which produces the sensation of brightness, in terms of the luminous intensity in a given direction ε (usually towards the observer) per unit area of an emitting, transmitting or reflecting surface. It is the luminous intensity of the light emitted or reflected in a given direction from an element of the surface, divided by the area of the element projected in the same direction.

Symbol: L

Unit: candela per square metre (cd/m²)

NOTE — The luminance L, in candela per square metre, of a perfectly matt surface is given by the formula

$$L = \frac{\varrho \times E}{\pi}$$

where

E is the illuminance, in lux;

ϱ is the reflectance of the surface considered.

3.2.5 reflectance: The ratio of the luminous flux reflected from a surface (Φ_r) to the luminous flux incident (Φ_o) on it.

The reflectance depends on the direction of the incident light, except for matt surfaces, and on its spectral distribution.

Symbol: ϱ

Formula: $\varrho = \dfrac{\Phi_r}{\Phi_o}$

3.2.6 luminous efficacy (of a light source): The quotient of the total luminous flux emitted by a source to the total power input to the source. (If the power loss of the control gear is included the term circuit efficacy should be used.)

Unit: lumen per watt (lm/W)

3.2.7 correlated colour temperature (of a light source): The temperature of the full radiator (black body) that emits radiation having a colour appearance or chromaticity nearest to that of the light source being considered.

Symbol: T_C

Unit: kelvin (K)

3.2.8 colour rendering: The colour rendering of a light source is the effect of that source on the colour appearance of objects compared with their colour appearance under a reference illuminant.

3.2.9 general colour rendering index: Value intended to specify the degree to which objects illuminated by a source have an expected colour relative to a reference illuminant.

It characterizes the degree to which the colours of eight test samples illuminated by the source conform to those of the same samples illuminated by a reference illuminant, suitable allowance being made for the state of chromatic adaptation (see CIE Publication No. 13.2).

Symbol: R_a

NOTE — R_a has a maximum of 100, which occurs when the spectral distributions of the test source and the reference source are substantially identical.

3.3 Interiors and systems

3.3.1 work system: The work system comprises a combination of people and work equipment, acting together in the work process, to perform the work task, at the work space, in the work environment, under the conditions imposed by the work task.

3.3.2 work space: A volume allocated to one or more persons in the work system to complete the work task.

3.3.3 work plane: The plane in which work is actually done.

3.3.4 reference work plane: A notional horizontal plane on which average illuminance is calculated for design purposes.

NOTE — Unless otherwise indicated, it is assumed to be 0,85 m above the floor (in the USA 0,76 m and in the United Kingdom 0,7 m for office tasks).

3.3.5 general lighting: Lighting designed to illuminate the whole of an area to approximately the same illuminance.

3.3.6 localized lighting: Lighting designed to illuminate an interior and at the same time provide a higher illuminance over a particular part or parts of the interior.

3.3.7 local lighting: Lighting for a specific visual task, additional to and controlled separately from the general lighting.

3.3.8 light loss or maintenance factor: Ratio of the illuminance provided by an installation at some stated time, to the initial illuminance when installed.

3.3.9 utilization factor (USA: coefficient of utilization): Ratio of the luminous flux reaching the work plane to the total luminous flux of the lamps in the installation.

4 Parameters influencing visual performance

The nature of the worker's visual system will ultimately determine the effectiveness of the design of the visual environment. In practice the effectiveness of the visual system is measured in terms of visual performance. The understanding of the capabilities of visual performance shall be in terms of the interaction between the visual system and the characteristics of the tasks seen within their environment and so cannot be viewed in isolation. Consequently, visual performance shall be considered in relation to those factors which are its major determinants.

The term "visual performance" is used to indicate quantitatively how a person "performs" in terms of speed, accuracy and probability of detection when detecting, identifying and responding to details in his visual field. Visual performance depends both on intrinsic task properties (size, shape, position, colour and reflectance of detail and background) and on the perception as influenced by the lighting.

Visual performance is, however, influenced by parameters such as glare, non-uniformity of illuminance, visual distraction, nature of the background, and the design of the work space in general.

"Fatigue" may occur after prolonged work under poor lighting conditions (low illuminance, non-uniformity, distraction, discomfort glare) and amongst others may consist of:

— fatigue of the central nervous system as the result of the effort required to interpret unclear or ambiguous signals;

— body muscle fatigue due to having to maintain an unsuitable posture in order to alter the task distance or avoid distractions or unwanted reflections which may occur, for instance, in a drafting task.

Localized muscular strain (for example of neck muscles) can also occur, for example in work involving the use of microscopes.

4.1 Visual task components

Visual perception may be considered to depend on the following components of the stimulus:

a) contrast;

b) size, form and texture;

c) movement and time available;

d) position of the image on the retina;

e) colour;

f) luminance.

4.1.1 Luminance

Under normal conditions, increases in illuminance produce an improvement in visual performance which is initially rapid but eventually flattens off at a level at which further increase in illuminance produces no effect.

The visual performance of tasks of small size and/or low contrast can be improved by providing high levels of luminance (i.e. by increasing illuminance), but the performance of tasks of large size and high contrast rapidly reaches a maximum at moderate values of luminance.

4.1.2 Contrast

The perception of an object in its surroundings is mainly dependent on the contrast, in terms of luminance and/or colour, between the object and its background. Whenever possible, tasks and lighting should be designed to optimize contrast.

Within certain limits, as luminance is increased so is the sensitivity of the eye to contrast. Sensitivity is also affected by the gradients of the boundaries between the two luminances or colours, but is reduced by too large a variation in luminance and colour within the visual field surrounding the task to be perceived. For example, if a bright source of light is within the field of view, disability glare will cause an apparent reduction of contrast. A reduction can also be caused by looking away from the task towards a more brightly lit area, causing a brief change in the adaptation of the eye (transient adaptation).

Contrast can also be reduced by veiling reflections. This occurs when high luminance is reflected by the task towards the eyes and thus veils, or interferes with, the perception of the task. In particular, reflections of light sources in specular or semi-specular visual tasks can result in substantial losses in contrast. Adequate diffusion of the lighting, for example, by light reflected from the ceiling and/or walls or light directed on to the task from the side or behind the person, normally avoids this.

4.1.3 Size, form and texture

Discrimination of size, form and texture, a complex psycho-physiological process of recognition of the environment, involves at least three functions: the perception of contrast, the resolution of visual details, and the perception of depths and distances.

Conventionally, the resolution of visual details is expressed quantitatively and is dealt with by the term visual acuity. Visual acuity is a function of the quality of a person's eyesight and of the environmental characteristics and, in particular, the magnitude of the perceived luminance.

Manipulation of size can be an important means of improving visibility. For example, performance can often be improved by enlarging the detail, bringing it nearer to the viewer or by using optical aids.

The perception of depth, relief, and distance depends not only on the occulomotor functions, such as quality of binocular vision, and on intellectual functions, such as memory of size and form of known objects, but also on the interpretation of contextual cues as illustrated in the creation of optical illusions. Perception of texture depends upon the pattern of shadow and light on a surface.

When designing the lighting for a particular task in order to provide the required luminance levels, care shall be taken that directionality and diffusion of the light do not reduce the contrast required for the perception of texture and form of objects by excessive diffusion of the light. Some shadow is often helpful in perception (see 5.8), but some types of shadow will make it more difficult. For example, too many shadows can be confusing and misinterpretation of the shadow pattern is possible.

4.1.4 Colour

Colour is an attribute of light which contributes considerably to the general impression of our environment as well as to visual performance. In particular, it is useful in the quick and easy identification of objects in the work space.

Colour perception improves as illuminance increases, within certain limits. Colour perception varies across the retina of the eye. Colour discrimination is at its best in the central area of the retina.

Colour constancy describes the way in which colours are perceived in relation to each other. The colours of the scene maintain a relatively constant relationship under light having a spectral composition sufficiently similar to that found in daylight. However, if the spectral composition deviates too much from this, colour constancy is not retained, and the colour appearance of the scene will change. Colour appearance is dependent not only upon the spectral composition of the light, but also upon the characteristics of the surface examined, the luminance, colour contrasts and the state of colour adaptation.

The eye can perceive quite small differences in colour between two adjacent surfaces even if the luminances are identical, but comparison with remembered colours is more difficult. Different light sources can improve or reduce discrimination of certain colours.

However, defects in colour vision occur in some individuals, and this can alter the appearance of colours and the power of discrimination between them, and may be important in some circumstances for certain occupations (see 4.3).

4.1.5 Movement and time available for viewing

The perception of motion requires movement of the image of the target on the retina. The *fovea* of the eye is more sensitive to the perception of movement than is the periphery. The peripheral area of the retina is relatively more sensitive to motion than to form so the eyeball turns toward the moving target to bring the image into the centre of the retina for more detailed inspection.

The accuracy of perception of movement depends on speed, size, form and contrast. Also, visual perception of an object depends on the time available for viewing. A brief glance may suffice if it is a large, high contrast object. A prolonged gaze may be needed if it is not. The visibility of a moving object can be improved by allowing the eye to follow it over an adequate length of its path. If the speed of movement across the visual field is too high or the path is too erratic, or both, visibility deteriorates very rapidly.

4.1.6 Position of image on the retina

Visual acuity, the ability of the eye to resolve fine details, decreases rapidly as the retinal image of the target becomes displaced from the central part of the retina (*fovea centralis*). For tasks which require the recognition of details the visual system performs with maximum efficiency when the target to be viewed falls on the primary line of sight and its image falls on the *fovea*. Flicker is more easily detected in the periphery of the retina.

4.2 Lighting characteristics

For the interaction of luminance and directionality with task attributes, see 4.1. This clause deals primarily with glare and flicker.

4.2.1 Glare

Glare is experienced if the luminance of luminaires or windows is excessive compared with the general brightness in the interior (direct glare) or when such light sources are reflected in glossy or semi-matt surfaces (reflected glare).

Glare can take one of two forms, which sometimes occur separately but are often experienced simultaneously. The first is known as disability glare and impairs the vision of details or objects without necessarily causing discomfort. The second is known as discomfort glare and causes discomfort without necessarily impairing the vision of details or objects.

In many interiors, for example offices, but not necessarily industrial premises, discomfort glare is likely to be more of a problem than disability glare. Measures taken to control discomfort glare caused by luminaires and windows will normally take care of disability glare also.

Glare may also occur by reflection from surfaces with high reflectance, especially where bright sources and specular surfaces such as polished metal are involved. When a bright image reaches the eyes it may cause discomfort and prove distracting to workers. Reflected glare may comprise both disability and discomfort glare.

4.2.1.1 Discomfort glare

Discomfort glare is normally experienced as a feeling of discomfort which tends to increase with the passage of time and may contribute to fatigue.

Discomfort is greater the higher the luminance of the sources, the greater the solid angles they subtend, and the greater their number within the normal field of view. It is lower the greater the angle formed by the direction of the source and the visual axis, and the higher the luminance of the background. Other parameters such as the characteristics of the eyes of the individual subject and the degree of visual concentration on the visual scene may also affect the degree of discomfort experienced.

Normally, the background luminance controls the general adaptation level of the eye. When the source becomes large, for example, in the case of a window, the effect of the source luminance on the adaptation level has to be taken into account.

International agreement exists on the extent to which the above parameters such as source luminance, source area and background luminance affect the degree of glare. Research in several countries has related values of these parameters to the subjective assessment of glare sensation.

4.2.1.2 Disability glare

Disability glare usually occurs when a large source of low luminance (or a small source of high luminance) is seen close to the line of sight to the visual task. An example is the difficulty in reading signs placed in front of, or close to, a window through which the sky is visible.

4.2.2 Flicker

Fluctuations in light, either from a source or from an illuminated area in the field of view, are perceived if the frequency of fluctuations is low. This phenomenon of "flicker" can be troublesome and may give rise to effects such as annoyance. It varies greatly from individual to individual, as does the degree of discomfort experienced.

The frequency of flicker that can be perceived depends on the luminance and area of the source or illuminated field, the position at which its image falls on the retina, the shape of the luminance-versus-time curve and on the amplitude of the fluctuations. Fluctuations of light can also cause a "stroboscopic" effect, which can cause objects to appear to move jerkily or can mask the true speed of rotation of rotating objects (see 5.9).

4.3 Eyesight

The visual process is a complex system both in terms of perceiving the object and in general reactions to the visual environment. In normal health the visual system is to a large extent self-regulating and will adjust itself to maximize the clarity of the transmitted information.

However, stress may be produced by excessive demands or conflicts connected with accommodation, adjustment of pupil diameter, or eyeball positioning. In the case of close vision, two types of mechanisms are combined which may cause strain. These are maintaining of convergence of the visual axes and accommodation. This should be taken into account in the design of the task and the work space.

The characteristics of the eye vary from individual to individual and change with age. They also depend upon certain diseases, for example diabetes. The most important change in the older eye is that the range of accommodation is reduced. Consequently, the use of correctly prescribed optical aids is helpful. Other physical changes in the ageing eye are

— reduction in light transmission through the eye which is important in very dimly lit conditions;

— increased scattering in the eye, creating greater sensitivity to glare (particularly disability glare).

Provision of adequate and glare-free illumination is thus even more important for older workers than for young people; greater attention should therefore be paid to these aspects.

4.4 Work space variables

Parameters such as visual field constraints, adequate postural requirements, etc., are not dealt with because they are beyond the scope of this International Standard. However, it is anticipated that such parameters will be taken into account in the application of good lighting practice as outlined in clause 5.

5 Lighting criteria

The lighting characteristics of the visual environment affect both the physiological visual functions (visual performance) and the psychological visual functions (comfort) and may thus contribute to the performance, safety, visual comfort and satisfaction of man in his visual environment. The criteria that shall be satisfied by lighting for this purpose are dealt with in this clause.

5.1 Lighting requirements

The lighting of an interior by daylight and electric lighting should provide the optimum conditions for performing the tasks required and the appropriate visual environment when looking away from the task for relaxation or change of task. Special requirements may be needed in certain commercial, industrial, and other applications (e.g. hospitals).

The visual impression of an interior is influenced by the appearance of the following surfaces:

a) main visual objects: for example, the tasks, the faces of people, and equipment;

b) large surfaces in the interior: walls, ceilings, floors, windows (at night) and surfaces of equipment;

c) light sources: luminaires and windows (during the day).

5.1.1 Lighting and design of task

In a work system the visual field of an occupant is different depending on whether the occupant is concentrating on a task or looking away for relaxation. The criteria that shall be satisfied are different for both situations. For this reason a distinction is made between lighting of the task and lighting of the environment. The effectiveness of lighting the task is judged mainly by the criteria of visual performance, which are influenced by the parameters discussed in clause 4. As the lighting of the environment can avoid causing distraction, unfavourable adaptation, and discomfort occurring in the field of view while performing the task, it can also play a part in assisting visual performance, which in turn improves the comfort and satisfaction experienced in carrying out the task.

In addition to contrasts of luminance, the visual task usually includes some colour contrasts; these can be used to improve conspicuity, especially when luminance contrasts are low.

5.1.2 Lighting of the environment

The relationships of the luminances and colours of the surfaces of the environment should be appropriate to the function of the interior, visually pleasing and free from glare.

Among the objectives sought, by providing appropriate lighting of the environment, are the following (not in order of priority):

a) to give the space adequate brightness in order to clearly define it;

b) to facilitate safe and easy movement in the interior;

c) to aid concentration on the task areas;

d) to provide areas of slightly lower luminance than the task areas;

e) to achieve natural modelling of faces and soften harsh shadows by the correct balance of directional and diffuse light;

f) to reveal the occupants and contents of the interior in acceptably "natural" colours by the use of light sources of good colour rendering quality;

g) to produce, in a working interior, a pleasant variety of luminance and colour that contributes to the well-being of the occupants and to the reduction of work stress[1]. One possible solution is to have small bright areas in the visual environment but not within the direct line of sight to the visual task;

h) to encourage cleanliness by choosing light colours, particularly for floors and (in a workshop) machinery.

Certain elements may be found to be in conflict and appropriate compromises have to be found without sacrificing safety requirements and well-being.

1) For the definition of "work stress", see ISO 6385.