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Guidelines for Visual Ergonomics – Lighting and Vision in the Workplace

Guideline 7

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Guidelines for

Visual Ergonomics

– Lighting and Vision in the Workplace

Guideline 7, English version 1

About the guidelines

The purpose of these guidelines is to provide Occupational Health Services and work environment consultants with a research-based foundation to support the practical work of achieving good visual working environment in various types of workplaces.

These guidelines are designed to be applied mainly in Occupational Health Services, or by work environment consultants. Portions of the guidelines are intended to provide support for employers, such as supervisors with work environment responsibilities, individuals working with work environment issues, individuals working with HR issues, purchasers of luminaires and equipment, and those ordering Occupational Health Services. Safety representatives and individual employees also constitute target groups that can make use of portions of these guidelines. The guidelines may also be useful to architects, lighting consultants and lighting designers in enabling good cooperation with Occupational Health Services.

These guidelines do not include measures for people with eye diseases or severe vision impairments, nor do they cover environments other than those normally encountered in working life. There are also a number of different occupations and job tasks that have special requirements in terms of vision which are not addressed specifically in these guidelines. A further limitation is that the guidelines do not address the aesthetic design of lighting or work environments.

The work on these guidelines was initiated and the process of creating them managed by the Swedish Agency for Work Environment Expertise. This work has been authored by a project group consisting of researchers and practitioners. Other experts have also contributed to the creation of the guidelines by collaborating on and reviewing all or portions of the work, both from a quality standpoint and in terms of their practical application.

Note that the guidelines are originally written for a Swedish context and based on Swedish work environment legislation. Accordingly, several sections include references to Swedish legislation (for example, reference is made to AFS, which are Swedish regulations issued by the Swedish Work Environment Authority, available in Swedish at www.av.se), academic literature, and supporting materials available in Swedish. Readers should find out which rules apply and what kinds of similar support materials are available in their own context, to ensure legal compliance and adherence to best practices.

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Marie Dahlgren, Swedish Association of Occupational Health and Safety, read the guidelines and offered views on their orientation and scope.

The following active professionals in the field have shared their views on the contents and their practical application: Carola Jansson, Work environment engineer; Anders Johansson, Work environment engineer; Sandra Nordström-Ohlzon, Work environment engineer and certified physiotherapist; Helene Callert Jakobsson, Ergonomist and certified physiotherapist; Robert Howe, Work environment engineer; Johannah Olsson, Work environment engineer.

Declarations of interest

Hillevi Hemphälä developed the VERAM risk assessment method.

Reading instructions

These guidelines comprise five chapters with associated appendices. The introductory chapter introduces the field. It is followed by two chapters that address research-based facts, basic visual ergonomics terminology, and facts and principles for designing the workplace visual environment. The final two chapters are more practice-oriented, and offer guidance and support for the practical work. The chapters may be read independently, depending upon the interests of and knowledge already possessed by the reader in the area of visual ergonomics.

Introduction introduces the term *visual ergonomics* and how it affects work. It also offers an introduction to the guidelines and their chosen orientations.

Visual ergonomics – a brief introduction to the facts offers an overview of the three focus areas in the guidelines, i.e. light and lighting, visually demanding work tasks and the consequences of ageing, and addresses the impact of visual ergonomics on performance. A number of relevant research results are presented as well. This chapter is intended for those seeking an overview of the field of visual ergonomics, as well as those seeking to get up to date on current knowledge within the focus areas of the guidelines.

The workplace's visual environment addresses light, lighting and visual ergonomics terminology that recurs in the practical portions of the guidelines. This chapter includes technical lighting terms, recommendations and principles for the workplace's visual environment, as well as an overview of common vision impairments and how they can be corrected. The chapter is intended mainly for those seeking to expand their knowledge in the field of visual ergonomics, but it can also serve as knowledge support for those who have expert knowledge in the field of visual ergonomics.

Planning of light and visual ergonomics in new construction, renovation and extension discusses processes and methods that Occupational Health Services and other experts can use in supporting client companies in planning light, lighting and visual ergonomics, or in renovation of spaces, or for equipment. Methods and tools that can be used in dialogue with architects, purchasers and lighting designers are provided as well. The chapter is intended mainly for experts in Occupational Health Services and actors with similar expertise, but it can also serve as support for safety representatives and those with work environment responsibilities. The chapter is also intended for employers, and here they can find support for decision-making, financial calculations, and for procurements.

Visual ergonomics in Systematic Work Environment Management moves step-by-step through the investigative work, risk assessment, remedial measures, follow-up, and how visual ergonomics are incorporated into this process. The chapter presents processes and working methods, with a focus on making improvements in existing environments. The chapter concludes with practical examples of visual ergonomic risk assessments. It is intended primarily for experts in Occupational Health Services and actors with similar expertise, although sections will also be useful to work environment coordinators, safety representatives, and employees.

In addition to the appendices, the guidelines also contain forms and templates that can be downloaded from the Swedish Agency for Work Environment Expertise website.

Contents

Introduction

The field of lighting finds itself in a comprehensive technology shift, one that is affecting visual ergonomics at work. New LED technology is making it possible to design lighting systems that reduce energy needs and costs, while at the same time making it possible to create better and more pleasant work environments that promote health, wellbeing and performance. But new technology also means new challenges. Improperly designed LED installations can degrade the work environment, e.g. because of glare and flicker. To ensure a good work environment, the visual environment needs to be designed based on the available knowledge. These guidelines highlight that knowledge. They also show how workplaces and organisations can and should, with the support of Occupational Health Services and other experts, strive to create workplaces with good visual ergonomics.

The visual ergonomics field of knowledge relates to the conditions and assumptions surrounding the eye and the sense of sight, the design of lighting and the visual environment, and vision aids for facilitating sight and the performance of work. It is a broad field, with many different, technical, medical and behavioural sciences sub-areas. The orientation and scope of these guidelines have focused on three areas which, based on experience and research, are particularly important for health, safety, performance, quality and productivity. The three areas addressed in particular in these guidelines are: **light and lighting, visually demanding work tasks,** and **consequences of ageing.**

The guidelines also address eye and visual function, and the important demands that they place on visual working environment. More facts and information may be found in the chapter entitled *Visual ergonomics – a brief introduction to the facts,* see page 11.

The importance of visual ergonomics

Most of us need some form of light to be able to do their job. Good light and lighting improve the possibility to quickly, easily and clearly see and carry out work tasks in the best way. If the lighting is improperly designed, it will cause problems, such as glare and flicker.

The need for light depends on the work tasks in question, and adaptation based on different conditions and assumptions is also necessary. For example, age plays a major role, as our visual system changes as we grow older. This poses particular demands on the work environment and assistive devices. As retirement ages gradually rise, the proportion of elderly workers climbs ever higher, increasing the need to adapt lighting and the visual work environment.

The visual work itself is key in designing the workplace. This is even more important in connection with visually demanding work, such as work done at different viewing distances or while looking at display screens and information screens. The trend toward digitalisation entails more computer work, which demands concentration and gives strain on the eye, neck and shoulder musculature. Read more about the design of visual environments on page 24.

There is well-documented knowledge about the ways in which deficiencies in the visual work environment can give rise to health problems in the individual, such as visual symptoms, vision problems, musculoskeletal symptoms, mental and physical tiredness and stress. There is also established knowledge about the ways in which visual ergonomics affect organisations, mainly in terms of job performance, safety, quality, and productivity. Job and workplace design are thus important factors in terms of individual performance, health, wellbeing, corporate profitability, and sustainable growth in our society.

Taking advantage of opportunities to do it right from the start

The best opportunities for creating good visual workplace environments that are tailored to the operations they house arise in connection with new construction or the renovation of existing environments. This requires thorough planning with knowledge contributions from numerous fields, e.g. what work is to be done in the facility, the requirements and recommendations regarding light and lighting for the relevant operations, and knowledge regarding suitable equipment and products. With their broad expertise, Occupational Health Services can offer important input and collaborate in their clients' efforts in terms of planning and execution, thereby contributing to good workplace designs. One section of these guidelines, i.e. the chapter entitled *Planning of light and visual ergonomics in new construction, renovation and extension,* (see page 46), identifies methods and processes for how visual ergonomic aspects can be considered in connection with new construction, renovation and extension, as well as ways of improving existing workplaces. The guidelines also define the roles that Occupational Health Services and work environment consultants can play in these efforts.

Incorporating visual ergonomic aspects in Systematic Work Environment Management.

An employer's reality, like the role of Occupational Health Services in supporting its clients in preventing and remedying work environment deficiencies, often has to do with the existing day-to-day operations. The employer must study, risk-assess, remedy deficiencies and follow up its operations and initiatives on an ongoing basis, i.e. engage in. The chapter entitled *Visual ergonomics in Systematic Work Environment Management* (page 61) offers guidelines for how visual ergonomic aspects can be integrated into Systematic Work Environment Management.

Knowledge from various experts is important in designing visual environments

Visual ergonomics and lighting constitute a very broad interdisciplinary field that requires collaboration among numerous different occupational groups, including architects, lighting planners, electrical installers, lighting designers, opticians and production engineers. Within Occupational Health Services, work environment engineers, ergonomists, physiotherapists, occupational health physicians, occupational health nurses and behavioural scientists possess fundamental knowledge regarding visual ergonomics and lighting, based on their own areas of specialisation. Some of them also have in-depth training in the area of visual ergonomics.

The strength of Occupational Health Services is that collaboration among the various competencies can resolve complex visual ergonomic issues. In this way, Occupational Health Services and other experts can play an important role in providing knowledge support and methodological support to an employer. Experts need to be involved in both the preventive work of designing good work environments and in providing follow-up assistance when any sort of problem or trouble arises. Combined with new lighting technology, closer collaboration between the various competencies can reduce costs, energy consumption and the environmental impact, while at the same time improving health, wellbeing, and organisational efficiency.

Our hope is that these guidelines will encourage Occupational Health Services and actors with similar expertise to develop and expand their roles in connection with visual ergonomics and lighting and thereby be able to create both health benefits and operational benefits. This applies in connection with new construction, renovation and extension, and the hope is that work environment engineers and ergonomists/physiotherapists will contribute their various competencies in broad interaction with behavioural scientists, occupational health physicians and occupational health nurses. Hopefully these guidelines can also incentivise further training in the field of visual ergonomics and lighting among occupational health workers and similar actors. This will enable input in various types of projects so that those actors can offer good solutions for their clients and thus gain further experience in the field. The guidelines include a literature list for more in-depth exploration. The following reference is recommended as complements to these guidelines: *International Standard ISO 8995-1 followed by (1) and the European Standard EN 12464-1 (2) on light and lighting indoors.*

Visual ergonomics – a brief introduction to the facts

This introduction to the facts is intended to highlight and impart a deeper understanding of the knowledge on which the guidelines are based. This chapter discusses basic factors involved in the effects of light on humans, as well as the conditions, risks and consequences associated with different types of visually demanding work. It also compares differences between individuals and general changes in the eyes, and the ways in which visual function changes with advancing age. The section concludes with a discussion of the ways in which visual ergonomics impact performance capacity and operations.

The effects of light on humans

Access to daylight affects our daily activities throughout the year. Daylight influences our biological clock and circadian rhythm (24-hour rhythm, cycle of sleep and wakefulness), as well as influencing perception and neuroendocrine, neurobehavioral and cognitive functions (1, 3-6). The retina of the eye consists not only of rods and cones; there is also a type of photoreceptor that regulates our circadian rhythms. They are called *intrinsically photosensitive retinal ganglion cells,* or ipRGCs (1)(6). It is these cells which, communicating with our brains, regulate the melatonin level in the body, which in turn regulates our circadian rhythms. The degree of wakefulness can be increased by exposure to large amounts of light in cooler colour temperatures in the early and late morning hours.

To maintain a healthy circadian rhythm, we need more light in the morning and the most at mid-day. A lot less light is required in the evening and at night. If there is too much light at these late hours, it can be more difficult to fall asleep and the circadian rhythm will be affected (7). Warmer light in the evening and darkness at night make it easier to sleep. Those who work at night benefit from having a blue-free, more orange light with less blue light in order to maintain some of their circadian rhythm (3, 4, 7-10). If the degree of wakefulness needs to be increased in connection with some type of night work, this can be achieved using so-called light showers, i.e. exposure to very cool light over a short period (15–20 minutes) during the first hours of the night shift (11).

Proper light and lighting – fundamental for good visual ergonomics

The parameters in the visual environment that are known to affect our performance capacity comprise the **size and contrast of the viewed object,**

luminance ratios (differences in luminosity between various surfaces), **colour differences** and **retinal illuminance** (the amount of light entering the retina of the eye) (4, 12). Overly large differences in luminance in the field of view, overly low illuminance and flicker also affect our productivity and ability to learn (13). It is crucial for a sustainable working life that the visual environment and work tasks are to facilitate vision, as this has a major impact on wellbeing and health (14).

Daylight supplemented with artificial indoor lighting has been shown to be the best light solution for good visual comfort in a number of studies (10, 15-17). Glaring daylight should be avoided, as it affects performance capacity negatively (17). Screening, such as thick curtains, blinds or awnings, offers an effective means of preventing excessive glaring light from coming in through windows, while still – if possible maintaining the view. At non disturbing daylight situations, the shielding should be withdrawn to permit an outdoor view. The significance of **illuminance, luminance, glare** and **flicker** is exemplified in greater detail below.

Illuminance is the amount of light striking a surface. Illuminance is measured in lumens per square metre, or lux (lx)(1, 18). A sufficient illuminance ensures that we can see what we are working with and perform our work. Lower illuminances can sometimes be better for individuals that have photophobia, or a sensitivity to light (19). Higher illuminance may be necessary at times to ensure that we can see work tasks clearly in connection with highly visually demanding work, or with advancing age (18). One study of letter carriers showed that the lighting used in sorting shelves varied greatly, was glaring, and had overly low luminance. Letter carriers with vision problems sorted half as quickly as those without. The performance capacity of those with visual symptoms increased once the lighting had been improved via higher and more even illuminance and reduced glare, with the result that the differences between the groups vanished (20, 21).

Luminance refers to the brightness of the surfaces (actual light source, or reflectance) that we perceive. There are recommendations that luminance ratios must not be too high within the field of view, so as to avoid glare (1). Read more about luminance and luminance ratios on page 30.

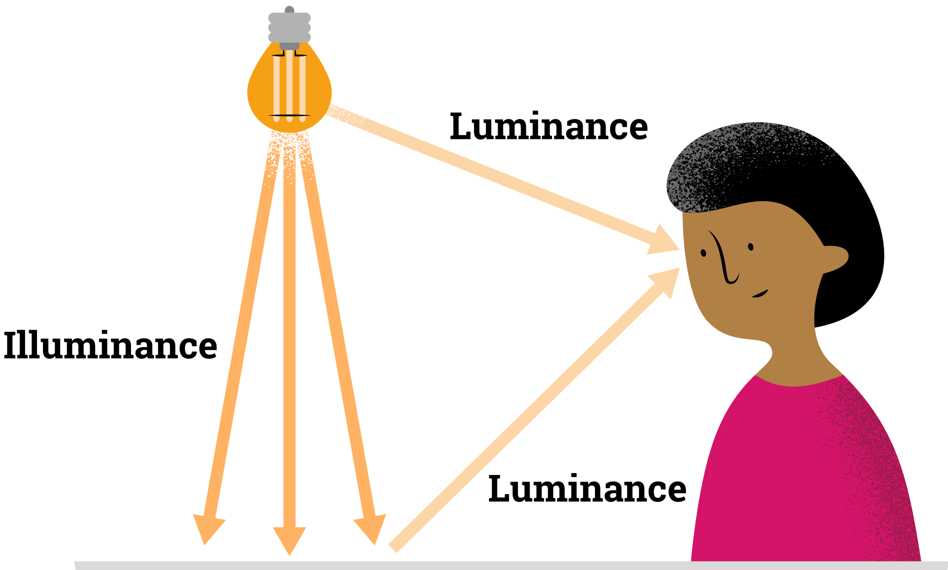


Figure 1. Difference between illuminance and luminance. Illuminance is the amount of light striking a surface, while luminance is the amount of light emitted from a surface, either reflected or directly from the light source.

Glare occurs when a luminaire or daylight from windows is significantly brighter than the surroundings. This is a common problem in workplaces. Glare increases when the light reflected from a surface is more than ten times brighter than the surrounding surfaces. Glare has negative effects on performance capacity and wellbeing (13, 16, 22-29). Glare is a factor which must be minimised in order to have a sustainable workplace with favourable conditions for good employee health. The risk of visual symptoms, headaches and neck/shoulder problems increases in connection with the presence of glaring luminaires or excessive contrasts in the field of view (26, 30).

Flicker or Temporal Light Modulation (TLM), regardless of visual or non-visual can have a negative effect on our wellbeing (see the section on flicker and temporal light artefacts in the chapter entitled *The workplace's visual environment,* page 24). Visual flicker affects our ability to concentrate and, at low frequencies, can trigger epileptic attacks (31, 32). A visibly flickering light source should consequently be replaced immediately. TLM from older luminaires (with conventional magnetic ballasts) can give rise to eyestrain and headaches (27, 31, 33-35). In the 1990s, electronic high-frequency drivers replaced conventional magnetic ballasts, making it possible to eliminate non-visual flicker from the newer luminaires and achieve almost flicker-free lighting.

But with the recent change to LED light sources flicker/TLM have again introduced potential problems in many workplaces. One reason for this can be that some LED light sources have inferior drivers that give rise to pulsed, frequency-based and often highly modulated light, causing TLM and sometimes flicker. Studies are showing that the TLM from LEDs can affect our cognitive function and wellbeing. It can cause headache, migraines and other problems, depending on the frequency (31, 33, 36). Completely flicker and TLM-free LED drivers and luminaires are available on the market, but are sometimes hard to find.

Visually demanding work

The process of vision

The vision process begins as light enters the eye through the cornea, travels through the pupil and lens, and falls onto the retina. The cornea has a fixed ability to bend light, while the lens adjusts its shape to focus, depending on the distance of the object being viewed. The rods and cones at the retina, converts the light into electrical signals that travel to the brain's visual cortex and beyond for interpretation. In typical work environments, the eyes, head, neck, and shoulder muscles work together and coordinate their movements when adjusting the direction of gaze. These chains of events are crucial for the process of vision and for the ability to carry out visual work tasks effectively and without adverse health consequences. The quality of the light at the work environment, in addition, must also meet specific contextual criteria to safeguard clear and comfortable vision. All visual work tasks share two basic requirements: a fully functional visual system and optimally designed visual ergonomic environments. Should these conditions not be met, the work becomes visually demanding. There are many reasons why visual work tasks may become challenging and there are several potential solutions. This section outlines common types of visually demanding work, detailing their specific requirements and potential impacts.

Work involving varying viewing distances

Performing tasks that require work at one or multiple varying viewing distances relies on a normally functioning visual system. A critical component of this functionality is the near triad, a synergistic activation of three interconnected oculomotor processes which are activated during near work (37, 38).

1. **Accommodation of the eye-lenses:** The ciliary muscle adjusts the curvature of the eye-lens to bring the image of the fixated object into sharp focus on the retina. This adjustment ensures a clear focused view of small and detailed visual objects situated at a close viewing distance. This ability, known as accommodation, is most effective in younger individuals. Over time, as a natural part of aging, the eye-lens become progressively less elastic, leading to a decline in accommodative ability. This condition, called presbyopia, generally starts to impact near vision in the mid-40s.
2. **Convergence of both eyes toward the point of fixation:** Convergence eye movements, controlled by the extraocular muscles, align both eyes toward the fixated object. This coordination allows the formation of a single, shared retinal image thereby enabling depth and stereoscopic vision.
3. **Pupillary constriction in both eyes:** The sphincter pupillae muscle in the iris reduces the opening of the pupil. This adjustment increases the depth of field and regulates light intensity entering the eye.

If any one of these near-triad processes fails, the others will too. For example, if the quality of the retinal image of a fixated object at near distance is impoverished because of lighting problems related to glare, the eye's ability to work together will be reduced. Problems with glare and a weakened sensory drive to accommodation response under these circumstances will also cause a problem with binocular eye movement control. The resulting reduced convergence eye-movements response can, in turn, impact negatively on reading ability in a computer work environment (39). For additional examples of failures of the near-triad process and related health, performance and productivity problems, see sections "Visual demands from binocular vision problems" and "Impact of visual ergonomics on performance and productivity" below.

To see small details, such as symbols or letters, comfortably and with good visual acuity is essential for performing all normal near work, including reading and writing. Tasks performed at one or several viewing distances can be carried out without adverse consequences if the demands on the visual system remain within its functional capacity. If work tasks are not tailored to align with an individual worker's visual capabilities, adverse health effects usually arise, along with issues related to performance and productivity. Visual ergonomic problems of this sort frequently occur when a significant proportion of time is spent working at viewing distances close to the accommodation/convergence near point - the shortest distance at which clear, single, and comfortable vision can be maintained. Visually demanding tasks are common in many occupations, particularly those requiring prolonged near work. Examples include all ordinary tasks involving digital screens (e.g., office work), those requiring precise eye-hand coordination (e.g., dentistry or surgery), or those necessitating ongoing scrutiny of visual details (e.g., quality assessments in industrial work).

Computer work

Both eye-related symptoms (e.g., eye fatigue, dry eyes, red eyes, and eye pain) and visual related symptoms (e.g., hazy vision, double vision, difficulty refocusing between distances, light sensitivity, and blurry vision) are common visual ergonomic problems associated with display work (40-44). These symptoms frequently arise from the use of various electronic screens, including desktops, laptops, tablets and smartphones (45). Such devices can place significant strain on the visual system, even in the absence of any pre-existing visual disorder.

The prevalence of these symptoms, sometimes referred to as *Computer Vision Syndrome* or *Digital Eyestrain Symptoms,* as measured in samples from cross-sectional studies, varies considerably, ranging from 12% to 98% (41). This variability is partly due to differences in how symptoms are defined and measured and due to the influence of independent risk factors within the specific populations (46). Gender and age play significant roles (47), with a higher prevalence observed among women and older adults. Symptom prevalence also increases among individuals who engage in prolonged computer work (over four hours per day) and in flexible work from distance in home environments not adapted for computer work (48). Related contributing risk factors include inadequate workplace lighting and non-neutral neck postures.

Eye and visual symptoms when identified in cross-sectional studies frequently co-occur with musculoskeletal symptoms primarily affecting the neck and shoulders. Reported prevalence rates range from 20% to 89% (49-52). The variability stems from differences in symptom measurement methods and the influence of contributing risk factors within the specific populations. One notable musculoskeletal risk factor associated with computer work, beyond posture alone, is static load placed on neck and shoulder muscles during prolonged low-intensity tasks, such as display work - particularly when performed without breaks or variation (53, 54). Straining the eyes in visually demanding conditions - such as poor lighting, glare (39), or incorrect eyeglass prescriptions (55), - can also increase muscle activity in the eyes as well as the neck and shoulders (56). The connection between visually demanding near work and the activation of neck/shoulder muscles, such as the trapezius, has been substantiated by both controlled laboratory experiments and field studies (57, 58). For further details on symptoms related to computer work, see the section titled *Common Symptoms Associated with Computer Work* on page 21.

Gaze stabilization and musculoskeletal strain

Work tasks requiring precise vision of small and/or detailed objects depend on the stimulation of photoreceptors specialized for high resolution and colour vision - the cones. During such work, the fixated object consequently must stimulate a limited portion of the central retina - the fovea furthest back in the eye, where the cones for detailed vision reside. Even a slight deviation in gaze angle from the central fovea will impair the visibility of the fixated object. As little as half a degree deviation from a foveal fixation will result in an impaired vision (38). The retinal stimulation therefore must remain accurately aligned over the fovea throughout the duration of the task, regardless of any ongoing head or body movements. Continuity in gaze direction is enabled by automatic reflexes that activate the eye-muscles, and the muscles stabilize the head and torso. The vestibular reflex enables the eye to maintain fixation on a stationary object while the head is moving. High demands on gaze stabilization during visually demanding tasks at near distance that simultaneously require precise eye-hand coordination can lead to increased activation of the neck and shoulder muscles. For example, work in the oral cavity performed by dentists and dental hygienists place significant demands on the visual system, which can contribute to the development of musculoskeletal symptoms, including fatigue, or pain, in the neck and shoulders.

Visual demands from binocular vision problems

With uncorrected or incorrectly corrected vision defects, or if the accommodation and convergence near point is not age appropriate due to other reasons - such as accommodation or convergence insufficiency - ordinary visual work tasks at near distances will be perceived as more demanding. Accommodative and non-strabismic binocular dysfunctions are visual disorders that affect the subject's binocular vision and visual performance, particularly when performing work tasks requiring near vision. Individuals with binocular vision problems must allocate more effort to perform the same amount of near work as others without these problems, which may draw from their psychological and physiological resources. Due to the efforts involved in prolonged near vision, the visual system may suffer a loss of efficiency, thus hindering near visual activities and provoking visual symptoms. Binocular and accommodative problems may alternatively cause the worker to avoid demanding near work and thus report no symptoms.

Accommodation insufficiency (AI) refers to the reduced ability of the eye to adjust its focus for near objects, leading to difficulty in achieving or maintaining clear vision at close distances. This condition occurs before the natural age-related decline in accommodative function, known as presbyopia, which typically begins around age 40. The prevalence of AI varies between studies because of varying definitions and differing study populations. It is generally estimated that approximately 6% of individuals aged 20 to 40 may suffer from this disorder. (59)

Convergence insufficiency (CI) is another example of a relatively common binocular vision disorder characterized by the inability of the eyes to work together effectively when focusing on nearby objects. This condition hampers near vision tasks, such as reading and writing on paper or on digital screens. Although CI can affect individuals of all ages, its prevalence increases with advancing age. Research suggests that up to 40% of people aged 70 and older may experience diminished convergence eye-movements when fixating objects at near distance. (60, 61). CI in older age is a consequence of progressively stiffer eye lenses and deactivated ciliary muscles. Even with sufficient lighting and newly fitted reading glasses the difficulties in finding focus may persist if the convergence eye movements are not adapted properly. This can lead to squinting, although, in most cases, the eyes have reserves that can compensate for this issue.

Binocular vision problems - when the eyes fail to cooperate as they should - are caused by inherent or acquired issues in the eyes' ability to work together and can lead to symptoms such as tired eyes, pain in and around the eyes, headache, blurred vision, poor visual acuity or ability to focus, and double vision, along with a reduced ability to focus the eyes for near vision. Binocular vision problems have been identified as a potential risk factor for chronic musculoskeletal disorders (62, 63). Mental or physical fatigue leads to more frequent symptoms of accommodation and convergence insufficiency, thereby complicating the management of binocular vision symptoms.

Postural strain from visual demands

All visual tasks, whether near or distant, begin with a targeted eye movement to align the fovea over the fixated object of interest. In normal vision and with absence of presbyopia this alignment activates the near triad, resulting in a clearly focused single view of the fixated object. Subsequently, the body - including the head, neck, and shoulders - quickly adjusts, if needed, to help maintain this focus. The adjustments are made to reduce the need for excessive vertical or horizontal eye rotations, allowing the eyes to remain near their neutral position, approximately 15° of downward rotation within the eye socket, thereby minimizing strain. When objects are positioned within 0-30° downward rotation, the eyes alone typically maintain fixation. However, for larger deviations, the body compensates by adjusting its posture to reposition the eyes, thereby preventing or alleviating symptoms of eye fatigue while maintaining the foveal fixation. Examples of visually demanding tasks that can lead to stressful postures include electricians working above their heads, e.g. with ceiling installations while standing on ladders. In such situations, they must extend their heads into non-neutral positions to align their fovea with the visual target, which can result in physical strain. One solution to improve this situation is using glasses with the area for short distance viewing in the upper part of the glass, or glasses equipped with a prism that directs the gaze upwards, see *Tips on special solutions/measures for some occupations electricians* on page 80.

Increased visual demands from high or low object placement

The ability to work comfortably at a close viewing distance, how near and for how long, is influenced by whether the task is performed above or below the individual's optimal vertical gaze direction. Tasks that deviate from the optimal gaze direction, approximately 15° below the eye's horizontal plane (64) and simultaneously impose high accommodation and convergence demands, are common in many professions. Examples include office work involving high- or low-placed display screens, or tasks with handheld computers and information screens. Such setups can lead to musculoskeletally strenuous working postures when ”the eye controls the body ” causing the individual to adjust their posture to align the fovea over the object of interest. This is especially evident when reading text on handheld devices like smartphones, or information screens. Too small a character size on such screens, which makes reading more difficult, can also steer the body into working postures that improve visibility of the written text but that are musculoskeletally strenuous. Tasks requiring an upward gaze, in addition, increase the risk of exposing the visual system to glare. An upward gaze also exposes more of the cornea to dry and/or polluted air, which heightens the likelihood of local eye irritation. (65)

The impact of individual differences and personal risk factors

Each employee's unique bio-psycho-social circumstance influences their susceptibility to develop symptoms of discomfort, fatigue, pain and related issues caused by high visual demands (66). External factors, including the physical and psychosocial work environment, along with internal factors such as age and health status, collectively determine the individual's resilience in managing and tolerating symptoms linked to high visual demands. Individuals with pre-existing health conditions (e.g. a non-traumatic concussion) that simultaneously are exposed to high visual demands may be particularly vulnerable to developing symptoms and health problems. (67)

The effects of ageing on visual function

Changes in the eyes and visual function occur with advancing age. Some of these changes are universal, but when they occur varies from one individual to another. Furthermore, various eye diseases can arise which affect visual function. The risk of developing eye disease increases with advancing age, but specific eye diseases are not addressed in these guidelines. The text regarding ageing is based on the following references in the reference list (68-77).

One common and normal change that comes with age is degraded **accommodation capacity,** i.e. the near point (the distance at which it is possible to see clearly) gradually shifts forward. The individual also finds it more difficult to focus. Changes are noticeable as early as one's 40s, and progress with advancing age, albeit less rapidly past the age of 60. Everyone is affected but, as noted above, the age of onset varies greatly among individuals. Accommodation capacity decreases because the lenses become more rigid, and the eye muscles weaker. The eyes also find it more difficult to converge. Some people may have problems with hidden strabismus, which can cause temporary double vision and in turn cause eye symptoms such as eye fatigue. In addition to optical correction for seeing close up, ageing eyes also require stronger and appropriate lighting. Reading glasses or glasses adapted for the viewing distance and which increase the eye's refractive power are the most common remedies.

Cataracts are one of the most common age-related changes that affect the eyes. The lens becomes cloudier and yellowish. Such cloudiness can begin after the age of 40, but there are major individual variations. Roughly half of 70-year-olds are expected to have these problems. The clouding may be accelerated by ultraviolet and infrared light. A clouded lens spreads light over the retina, resulting in reduced visual acuity and greater sensitivity to glare. The visual impression is like having a blurry greyish-yellow veil through which the colours become paler, particularly the blue nuances. Blurred vision and double vision can also occur in connection with glare. Yet another consequence of lens clouding is less light reaching the retina, so that the surroundings are perceived as darker. Supportive measures can include increasing the illuminance but that might also cause increased disturbing glare. Many elderly therefore prefer lower illuminance even though the visual impression is perceived as a little bit too dark. Other measures are targeting the light, reducing the risk of glare and contrast glare, and creating more optimum luminance ratios. Eye protection must be worn when working in proximity to or with ultraviolet or infrared light. One effective measure is to replace the individual's own lens with a synthetic copy, which is a relatively simple surgical procedure (the world's most common with e.g. more than 4.3 million replacements each year among the 450 million EU inhabitants).

Pupil diameter decreases with advancing age, and the pupillary contraction rate decreases. This means that less light enters the eye and reaches the retina, but also that it adjusts more slowly to changes in how much light is entering. Together with lens clouding, this means that a 50-year-old needs roughly twice as much light as a 20-year-old, while a 60-year-old needs roughly three times as much. Overly rapid changes or variations in brightness in the field of view should be avoided.

Dry eyes become more common with advancing age, particularly in women. Studies have estimated that just over 10% of all people between 65 and 69 years of age have dry eyes, and that over half of 60-year-olds have problems with lacrimation. Problems with dry eyes occur in part in connection with computer work, and can lead to discomfort or pain, and may affect vision. These problems may be exacerbated in environments containing air pollutants or static electricity. In addition to medical interventions, eye drops can be used, the air quality can be improved, and the work can be adapted so that elevated gaze directions are avoided.

Visual acuity begins to decline at the age of 50, in part as a result of a degeneration of various structures in the eye and, in some cases, disease. This leads to decreases in the ability to see small details, to distinguish contrasts, and in-depth perception. Steps that can be taken include increasing illuminance, creating clear contrasts between viewed objects and the background, and enlarging viewed objects when possible, e.g. text on displays. Glasses are another potential remedy.

Colour vision is affected as the lens turns more yellowish with advancing age. The ability of elderly people to perceive blue and purple nuances is affected most. Steps that can be taken include increasing illuminance and making sure that the light has good colour rendering or, if possible, making the colours of the viewed object more distinct.

Night vision degrades with advancing age, and **dark adaptation** proceeds more slowly. These changes begin after the age of 40–50, and this ability differs notably between 20- and 70-year-olds. The changes occur as a consequence of, among other factors, the age-related changes in the eye described above. The available remedies include altering the work requirements so that the elderly need not work under low-level lighting, or to increase their work lighting.

The **functional field of view** shrinks with age, i.e. the ability to identify objects and activities in the peripheral field of view. Reaction times for signals increase, particularly in the peripheral field of view. Steps that can be taken include positioning objects and warning signals that must be identified more centrally in the field of view. Their contrasts and sizes can be increased, and they can advantageously be made more mobile or blinking.

Non-visual effects include the effect of light on the body's circadian rhythm, which was described earlier in this chapter. Because less light passes through the elderly eye and reaches the retina, it becomes even more important for the elderly to have plenty of access to daylight.

Among the most common and more specific **eye diseases** that become more prevalent with advancing age but affect only some people of working age include:

- glaucoma
- macular degeneration
- diabetic retinopathy

These diseases rarely occur before the age of 50, and usually appear in fewer than 10% of those who have reached the age of 70. Those affected experience degraded visual acuity and reduced contrast sensitivity. The measures that can be taken include increasing the size of viewed objects and their contrast with the background, reducing glare, and trying out glasses.

When designing new jobs and workplaces at which elderly people will be working, they should be adapted based on the visual requirements of that group, applying the principle of 'Designing for everyone'. The adaptations made for the elderly will also mean that younger people will enjoy better visual ergonomics. Moreover, adaptation for elderly individuals can be carried out in their existing jobs or workplaces by providing everyone with the means of making individual adjustments. Page 82 provides a checklist of recommendations for how jobs and workplaces can be adapted for older employees.

Common symptoms of deficient visual working environment

When we strain our eyes more than usual, we increase the load not just on the ocular muscles but also on the brain and, for instance, the neck and shoulder muscles. This has physiological and mental consequences for health, performance and productivity. Visual ergonomic deficiencies at the work environment may cause:

- visual symptoms (such as eye fatigue, photosensitivity, dry eyes)
- musculoskeletal symptoms (neck, upper arms, shoulders)
- headache, migraine

It is crucial to prevent these types of health problems, as it is more difficult to remedy them once they have arisen. There is also a risk of secondary consequences, such as degraded job performance, stress, negative effects on job satisfaction, etc. These can also lead to degraded performance capacity in the long run.

Common symptoms associated with display work

The symptoms that can arise in connection with non-optimal visual working environment in connection with digital devices such as computer work comprise the same overall group described in the preceding pages, i.e. **symptoms involving the eyes, symptoms associated with visual function, and musculoskeletal symptoms.** These are further specified in Table 1 (78, 79).

Table 1. Commonly occurring symptoms in connection with display work.

Symptoms involving the eyes	Symptoms associated with visual function	Musculoskeletal symptoms
• Eye fatigue	• Blurred vision	• Headache
• Gritty feeling	• Double vision	• Neck pain
• Dry eyes	• Difficulty focusing on close-up work	• Upper back pain
• Increased photosensitivity	• Seeing coloured haloes	
• Itching	• Seeing coloured haloes around objects	
• Teariness	• Sense of degraded vision	
• Redness		
• Eye pain		

Impact of visual ergonomics on task performance and work productivity

The economics of prioritising visual ergonomics

Visual ergonomics and lighting contribute to greater operational efficiency and utility. This section outlines why investments in visual ergonomic work environments are not only ethical and legal requirements but also financially sound. Such investments reduce symptoms associated with visually demanding tasks and thereby mitigate impairments in work performance.

Increased work performance because of improved visual working environment

It is well-established that good visual ergonomics and lighting improve quality and productivity in traditional industries and manual work tasks. Adequate visual ergonomic work conditions result in lower scrap rates, decrease the risk of accidents and absenteeism, and have a positive effect on health and wellbeing (80). Good visual ergonomics make it easier for an employee to gain visual control over their work, and thus to complete their job tasks quickly and correctly (81). Work can be performed in healthy postures, reducing stress on muscles and joints and preventing the development of mental strain by eliminating the need to compensate for poorly visible work-related objects (82-86). Better lighting can, for instance, reduce the risk of accidents (often slipping or falling accidents) by up to 60% (80, 87-89). Optimum lighting has long-term beneficial effects on employee wellbeing, alertness and performance capacity, and thus a positive operational effect as well; see Table 2.

Adequate visual ergonomic work conditions also positively impact speed and accuracy of ordinary office and computer work. Elimination of visual strain and discomfort directly improves productivity which otherwise can cause employees to take unnecessary frequent breaks, to work at a slower pace, or to avoid work. Elimination of time-consuming comprehension errors and a need to re-read 'blurry text' displayed on the screen also has a positive effect on productivity. Compensatory efforts to meet performance standards in suboptimal visual environments, in order to 'see clearly', increase mental and physical stress and have short-and-long term negative health consequences. In cross-sectional studies, the estimated production loss among computer-working office staff because poor visual ergonomics has been estimated up to 19%. (39, 40, 79, 90, 91).

Cost effectiveness and return on investment of visual ergonomics

Health economic research estimating the monetary costs of production losses due to poor visual ergonomics points to high costs in all sectors of work life (92, 93). Aggregated effects of combined health issues on productivity and monetary loss add up to significant numbers when many employees are affected for extended periods. The sequence of visual strain and performance impairments can quickly translate into substantial productivity and monetary losses. By taking appropriate visual ergonomic action these costs can be prevented. The return on investment will be favourable because the costs are negligible relative the monetary losses related to reduced work performance and productivity. Routines for regular vision testing, special work glasses, and other investments in a work environment with good visual ergonomics will always prove to be cost-effective. (94) Lighting costs typically account for just a fraction of payroll costs. A small investment in a good working environment is a 'win win' for all involved parts. Business strategies for streamlining operations should consequently include visual ergonomic measures. (95) Good visual ergonomics contribute to a sustainable working life and create added ethical value for the organization in the form of goodwill.

Table 2. Positive operational effects resulting from measures to improve visual working environment.

Type of work	Improvement	Work task	Operational effect
Postal workers	Increased and more even lighting, less glare	Mail sorting/no. letters sorted per unit of time	Those with eyestrain increased their productivity by 10% (20)
Electronics industry/ factory worker	Increased lighting from 800 to1200 lux	Manual electronics installation/production pace	Production rate increased 3% (83)
Metal industry/ factory worker	Increased lighting from 300 to 500 lux, or from 300 to 2 000 lux	Metal work/productivity incl. scrap rate	Total productivity increased 8–20% (96)
Healthcare/pharmacist	Increased lighting from 485 to 1 570 lux	Prescription writing/relative incidence of incorrectly written prescriptions	No. of incorrect prescriptions decreased 1.2% (84)
Industry/various types of work	Six studies of improved lighting, e.g. colour-temperature illuminance and task lighting	Assembly, packing and maintenance/productivity or production rate	Productivity increased up to 7.7% (83)

The workplace's visual environment

There are essentially three factors that affect visual performance and visual ergonomics: light, the design and visibility of the job task, and the eye's visual function. These factors are the focus of this chapter, which is intended to serve as support in the effort of creating the best possible visual environment in the workplace. The chapter is intended mainly for those in need of an orientation in basic visual ergonomics factors and concepts, and who wish to learn about the principles for designing a good visual work environment.

Figure 2 below illustrates how these factors affect our wellbeing and performance capacity, as well as the physical and psychosocial influence of the work environment on subjective symptoms and productivity. Simplified model by Hemphälä (97).

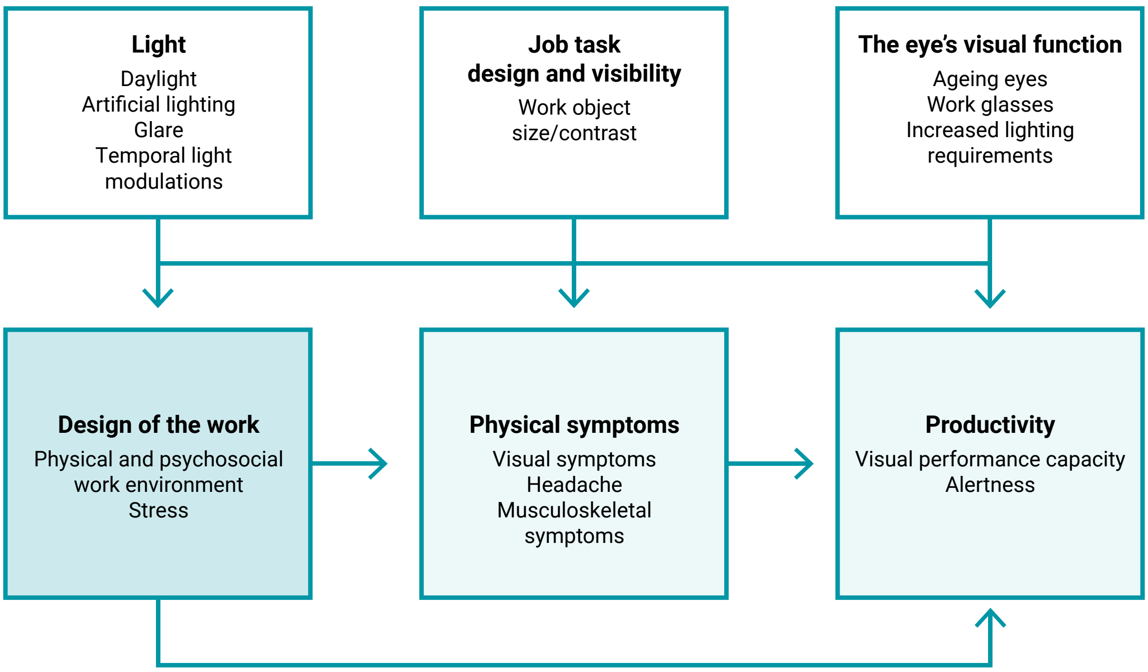


Figure 2. The influence of various factors on the visual environment and its effects on wellbeing and performance capacity.

Light, daylight and artificial lighting

The chapter entitled *Visual ergonomics – a brief introduction to the facts* describes how light, daylight and artificial lighting affect our visual performance capacity. The parameters that determine the quality of the visual environment with regard to artificial lighting and daylight comprise:

- illuminance
- glare and luminance distribution
- the direction and distribution of light – luminaire types and placements
- colour rendering and colour temperature
- flicker and light modulations

This chapter describes these parameters and how to optimise them, and offers recommendations and solutions for problems in common situations.

According to Swedish Work Environment Authority Regulation 'AFS 2023:12', which concerns workplace design, the aforementioned parameters must be taken into account in order to achieve high-quality lighting. It is also recommended that employers comply with the European standards regarding indoor (2) (SS-EN 12464-1) and outdoor (98)(SS-EN 12464-2) workplaces also covered in the international standard for indoor lighting ISO8995-1(1).

Detailed recommendations for lighting intensities for many different types of indoor workplaces are set out in European standard 'EN 12464-1:2021 Light and lighting – Workplace lighting – Part 1 Indoor workplaces' (1). According to the standard, three basic needs must be met:

- **Visual comfort,** whereby the workers experience a sense of wellbeing, which also contributes indirectly to a higher productivity level and higher work quality.
- **Vision performance,** whereby the workers can perform their vision-based tasks under difficult conditions and for extended periods.
- **Safety,** whereby the workers can perform their job tasks safely and with good visibility to e.g. reduce accidents involving falls, etc.

Lighting recommendations

The lighting standard (2) 'EN 12464-1:2021' offers recommendations as to what the work surface illuminance (designated $\bar{E}$m,) should be for various kinds of work. The standard includes a number of tables containing recommendations for general surfaces in buildings, industrial facilities and handiwork, office and retail spaces, public gathering places, educational facilities, healthcare facilities and transport facilities such as airports and railway stations. Table 3 below presents an excerpt from the standard that offers lighting recommendations for offices. Some additional tables are reproduced in Appendix 2. The tables published in these guidelines is reproduced from a part of the Standard SS-EN

12464-1:2021 with the proper permission granted to the Swedish Agency for Work Environment Expertise by the Swedish Institute for Standards, which is the owner and copyright holder of the Standard(s), and also sells the complete Standard(s) at www.sis.se, Tel. +46 8 555 523 10.

Table 3. Lighting recommendations for offices as per standard SS-EN 12464-1:2021, Table 34 (2).

Ref. no.	**Type of task/activity area**	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m, ceiling}$ lx	**Specific requirements**
		required[a]	**modified[b]**				**$U_o \geq 0,10$**			
34.1	Filing, copying, etc.	300	**500**	0,40	80	19	100	100	75	
34.2	Writing, typing, reading, data processing	500	1 000	0,60	80	19	150	150	100	DSE-work, see 5.9 Room brightness, see 6.7 and Annex B Lighting should be controllable, see 6.2.4. For smaller cellular offices the wall requirement applies to the front wall. For other walls a lower requirement of minimum 75 lx could be accepted.
34.3	Technical drawing	750	1 500	0,70	80	16	150	150	100	DSE-work, see 5.9 room brightness, see 6.7
34.4	CAD work stations	500	1 000	0,60	80	19	150	150	100	DSE-work, see 5.9.
34.5.1	Conference and meeting rooms	500	1 000	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4.
34.5.2	Conference table	500	1 000	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4.
34.6	Reception desk	300	750	0,60	80	22	100	100	75	If reception desk includes regular work station tasks these should be lit accordingly.
34.7	Archiving	200	300	0,40	80	25	75	75	50	

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table clarification

$\bar{E}m$(lux) indicates the mean value for illuminance on a work surface. UGR_L is the maximum value for glare for the situations listed in column 2, U_0 indicates the uniformity value for the illuminance on the work surface (min./mean), while R_a is the lowest recommended value for colour rendering. Example l: The table recommends at least 500 lux on the desk for office work with a uniformity value of at least 0.6, which means that the difference between the lowest value and the mean value on the work surface should not exceed 40%. The UGR value is given for each respective luminaire. An R_a value of 80 is the lowest permissible value for the light source's colour rendering.

Definitions of terms

Illuminance, $\bar{E}m$

Illuminance is the amount of light striking a surface. Illuminance is measured in lumens/m^2 or lux (lx).

Glare, UGR_L (Unified Glare Rating limit)

There are recommended glare ratings for uncomfortable glare – UGR_L – for luminaires to be installed. The glare rating varies depending on where the luminaire is to be placed, and the job tasks to be performed there. The lowest, and thus the best, glare rating is 10, the highest is 28. The UGR value that is appropriate for a given job task/workplace is found in the lighting recommendations (see complete list for various types of work in the tables in EN 12464-1 (2), and in a selection of the tables in Appendix 2. The rating for a given luminaire is found in the product information sheet from the supplier. One problem with UGR is that it is calculated in the best possible situation in one direction of gaze. If the position is changed just a little, a new calculation is actually needed. As a result, UGR calculations are usually performed only by professional lighting engineers. However, the rating may be of interest when purchasing luminaires. Bear in mind that the UGR value given for a luminaire can seldom be achieved in reality unless the visual environment at the location is optimum. See 'SS-EN 12464-1' (2) for more information about how UGR is calculated.

Uniformity value, U_0

The uniformity value is designated U_0, and is the lowest measured illuminance value (darkest area) for the inner work area divided by the mean illuminance value for the inner work area. The uniformity value can assume a value between zero and one (0–1). If $U_0 = 1$ then there is no difference in illuminance across the central work area, which means that the eye need not adapt to differing 'brightness' within the area. A low uniformity value characterises uneven lighting, which suggests a closer look at what is causing the unevenness, as it can cause eye fatigue and visual symptoms. If U_0 is greater than or equal to the recommended value, it is considered approved. Recommendations for uniformity values for various workplaces are found in 'SS-EN 12464-1' (2).

Colour rendering index, R_a
Recommendations for the colour rendering or R_a index are available for each interior; more about this in the section on *Colour temperature and colour rendering* on page 35.

Recommendations for work areas, surrounding areas and surfaces

If the recommended illuminance for a work area is 500 lux, then the illuminance in the immediate surroundings must be at least 300 lux; see example for an office workplace in Figure 3 on page 29. The illuminance should be highest across the work surface and can, to keep energy costs down, be slightly lower on the surrounding surfaces.

There are also illuminance recommendations for walls and ceilings for all types of spaces for indoor work. They are:

- Walls: $\bar{E}_m$ >50 lux with $U_0 \geq 0.10$
- Ceilings: $\bar{E}_m$ >30 lux with $U_0 \geq 0.10$

However, it may be difficult to increase the brightness on walls and ceilings in, for instance, storage rooms, as their design may be problematic due to the lack of uniform surfaces to illuminate.

The illuminance recommendations for offices, educational facilities, healthcare facilities, staircases and the like are higher than the general recommendations above. The recommendations for these are:

- Walls: $\bar{E}_m$ >75 lux with $U_0 \geq 0.10$
- Ceilings: $\bar{E}_m$ >50 lux with $U_0 \geq 0.10$

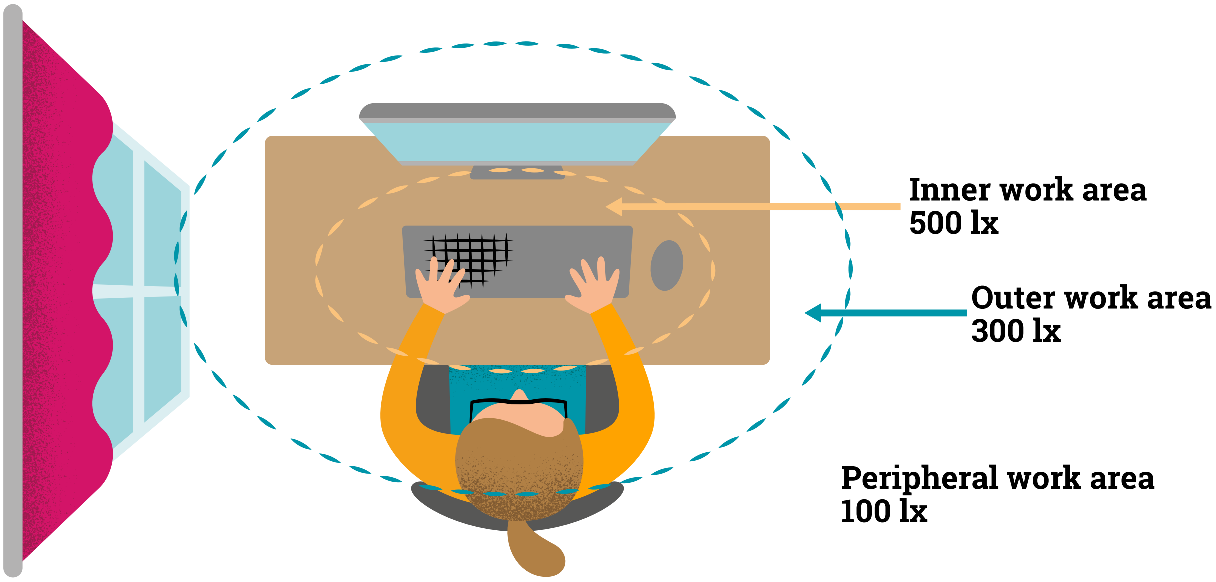


Figure 3. Examples of different work areas. The illuminance in the inner work area in this example of an office workplace must be at least 500 lux (horizontally).

Inner work area
The inner work area is the area in which the primary and visually demanding job tasks are performed, e.g. reading, writing, assembly or inspection. The lighting conditions within the inner work area must be optimum. If computer work is the main job task, the screen is also included in the inner work area. If the screen is stationary, the wall behind it is included in the inner work area.

Outer work area
The outer work area, also known as the immediate surroundings, encompasses the area directly adjacent to the inner work area. Luminance ratios should not differ more than 5:1 between the inner and outer work areas. The outer work area may include windows and walls, depending upon the type of job task. If computer work is not the main job task and a stationary vertical screen is being used, then windows and/or walls behind the screen are included in the outer work area.

Peripheral work area
The peripheral work area, also known as the outer surroundings, is the outer area of the field of view. No work is normally done in this area, but it may contain light sources that can produce glare. If the luminance ratios between the inner and peripheral work area is higher than 1:20 there is a high risk for glare. The lighting conditions in the area must be adapted for the activities occurring within it, such as passages to and from the workplace, or walks to fetch work materials.

Glare, luminance distribution and luminance ratio

The conformation of the luminance distribution in a room is crucial to achieve good visual ergonomics. The point is that the differences in 'brightness' in the room must not be excessive. The brightness of various surfaces must thus not differ excessively, but rather be spread to all surfaces, as otherwise there will be a risk of glare. If measurements point to major differences in the luminance values in the room, they may give rise to glare. Glare must be limited to avoid fatigue and accidents, and to reduce the risk of mistakes (2).

To achieve a good visual environment, the walls and ceiling need to be bright. Recommended reflectance values for some surfaces (2):

- Walls 0.5–0.8
- Ceilings 0.7–0.9
- Floors 0.2–0.4

Luminance ratios

To prevent the risk of glare, the recommended optimal luminance ratios between the inner, outer and peripheral areas are 5:3:1 (24). This means that the luminance in the inner area should be roughly five times higher than in the peripheral area, while the luminance in the outer area should be roughly three times higher than in the peripheral surroundings. The North American standard for office lighting claims that between a task and immediately adjacent (inner:outer areas) should not differ any more than 1:3 or 3:1, and for the work task and remote surfaces (inner:pheriperal areas) should not differ any more than 1:10 or 10:1(99). If the luminance ratio within the visual field (inner:pheripheral areas) are higher that 1:20 or 20:1 the risk for eyestrain increases (100).

Effects of luminance distribution:

1. The luminance distribution with the field of view affects the visibility of job tasks and may hamper the ability of the eye to adapt. This can affect visual acuity, contrast sensitivity and vision efficiency.
2. The luminance distribution can also affect visual comfort, i.e. the feeling of wellbeing.
3. Overly high luminances from light sources or daylight can cause glare.
4. Excessive differences can cause eye fatigue, due to the need to adapt to different 'luminances'.
5. Overly low differences can lead to a tedious and unstimulating workplace

How the luminance ratio is calculated (2 values)
Compare the average value within the work area to the highest value; this luminance ratio indicates the relationship between the luminances in the two areas, e.g. how the inner work area relates to a high-luminance surface in the peripheral work area. This ratio should not be higher than 10:1(99). According to the 'VERAM risk assessment method' (100, 101), there is a major risk of glare when the value exceeds 20:1, and if it is higher than 5:1 there is a low risk. Example: If a luminaire in the peripheral work area has a measured luminance value of 10 000 candela per square metre and the mean value in inner work area is 200 candela per square metres, we derive a luminance ratio of 50:1, which will produce strong glare.

Measurements of illuminance and luminance are key elements in the methods and checklists for visual ergonomic risk assessment recommended in these guides. Appendix 3 provides a protocol that can be used to support measurement planning and documentation.

Light direction and distribution – luminaire types and light distribution

The light on a work surface should come from almost directly above the individual working there (see Fig 4). It must not come from so far forward that one can see the light source or so long behind that it causes reflections of the light source in the work material or on the screen. Incorrect light direction is one of the most common workplace lighting problems. The angle of the light from the luminaire onto the work area and in the room must be pointed away from the line of sight in order to avoid reflections, and to reduce glare by achieving the best possible contrast conditions.

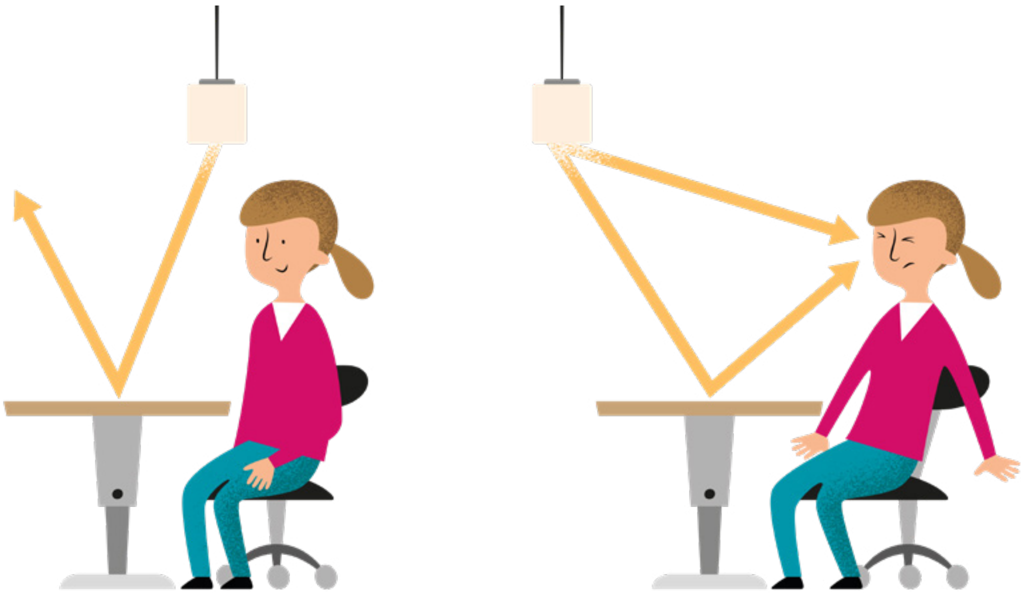


Figure 4. Principles of luminaires placement and light direction. The image on the left shows the correct luminaire placement and light direction, while the image on the right shows incorrect placement.

One simple means of controlling the light direction is, with pen in hand, to make sure that its shadow falls away from the eyes. If the shadow falls towards the eyes, then the luminaire placement is incorrect and the contrast will be degraded; see Figure 5.

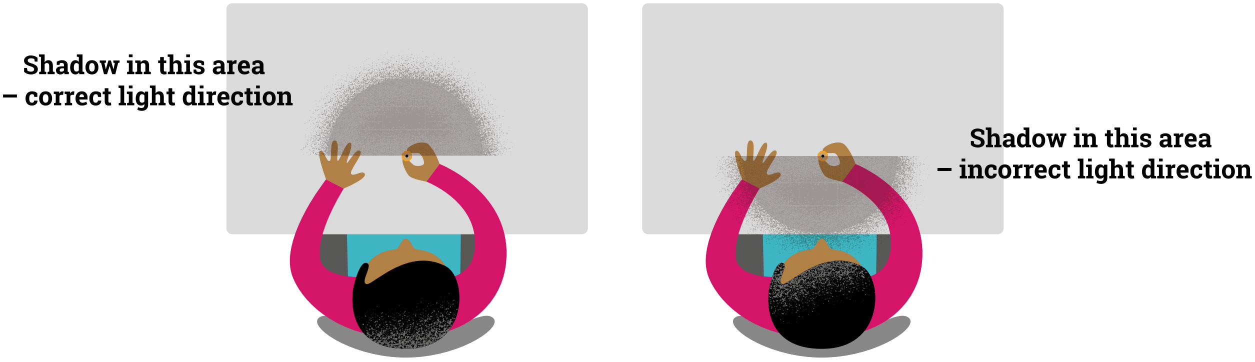


Figure 5. If the shadow of the pen falls away from you, the light is positioned properly; see image on the left.

Another simple way to check the incident light is to hold your hands, a magazine or similar as a hat with a brim (cap) over your eyes. If it feels more comfortable with such a brim in place, then glare of some sort is present. In the case of computer workers, if the work object becomes more distinct when your hands are used as a brim, the light is incorrectly oriented relative to your gaze direction.

Figure 6. The *hat-test* can be used to determine whether the light direction is correct, or if glaring and incorrectly placed luminaires are present.

Too much light towards a computer screen reduces the contrast on the screen. Luminaires with very small light apertures that 'spotlight' or 'downlight' can be very glaring, creating distinct shadows, and they should never be used as general lighting in an office landscape. Properly placed and well shielded, they can serve as very good complements to the office landscape's regular lighting.

The best recommendation is usually to position the luminaire above and parallel to the front edge of the desk (see Figure 7). The luminaire should consist of both indirect light upwards into the ceiling and direct light downward onto the work area. This type of light distribution (both indirect and direct light) allows the room to be perceived as bright, to reduce the amount of reflections, and to achieve good lighting on the work surface. The lighting planner must plan the lighting and select luminaires that do not cause disturbing reflections or glare. The lighting can affect screen visibility by reducing the contrasts on the screen resulting from too much light striking the screen, and reflections from the screen surface. Maximum of 3000 cd/m^2 is recommended for a normal brightness on the screen (2).

Figure 7. Principles for luminaires placement. The luminaire must be positioned above and parallel to the front edge of the desk. A suspended luminaire with both indirect light (from the ceiling) and direct lighting often provides a good luminance distribution.

There are a number of different types of lighting solutions that provide a good visual environment. Common types of luminaires include:

- **Pendant** luminaires with direct/indirect or both direct and indirect lighting. The ceiling is bright, and the differences between the luminaire's illuminating surface and the ceiling diminish.
- **Downlights** are luminaires, usually round, that are recessed into the ceiling or mounted on the ceiling. They provide only direct light. The surroundings are often dark, and the light source may then be perceived as glaring.
- **Surface mounted** luminaires, such as elongated fluorescent luminaires or LED luminaires. They can provide both direct and indirect light. The surrounding ceiling is often dark, and the light source is perceived as glaring, particularly if the luminaires are spaced a bit apart from one another. (Downlights is an example of surface mounted luminaires with only direct light).
- **LED panels/recessed** luminaires, often square shaped, providing only direct light. The surrounding ceiling is often unlit and dark, and the light source is then perceived as glaring.
- **Spotlights,** which are external and intended to spotlight, for instance, goods in a shop or art on walls. They are often very high-intensity, and can produce severe glare when one stands within the beam. Common in shops.

The lighting solution that normally provides the best visual environment consists of pendant luminaires with both indirect and direct light distribution. For more information about different types of luminaires, louvres and reflectors see chapter 8 in The Lighting Handbook (18).

Colour temperature and colour rendering

Both artificial light sources and daylight can be characterised based on two main properties:

- Colour temperature (the character of the light in terms of its colour)
- Colour rendering index, R_a (the ability to reproduce colours)

Daylight varies in these respects during the day, while the majority of artificial light sources are static unless controlled using dynamic lighting technology, such as *tuneable white.*

Light sources in most work environments must deliver good colour rendering. Colour rendering is expressed as an R_a index. R_a is the designation for colour rendering when eight colours are tested.

The highest R_a index value is 100. Light sources with an R_a index of 80 emit light with fairly good colour rendering. Certain environments have heavier demands in terms of colour rendering, and must have an R_a index/CRI of at least 90 (e.g. the graphics industry or surgical environments). The R_a index for a light source is given for the light source itself, or for the luminaire in which the light source is integrated.

Figure 8. Examples of colour rendering. R_a index of 90 on the left, and of 80 on the right.

The colour temperature of the light is measured in Kelvin (K). A warm white light source is at a maximum of 3 300 K, neutral white light is at 3 300–5 300 K, while a cool light source will be over 5 300 K. For more information go to chapter 6 in the Lighting Handbook (18).

Figure 9. Examples of colour temperatures. A colour temperature of 4 000 K is shown on the left, and of 2 700 K on the right.

Flicker and other light artefacts

In these guidelines, flicker refers to variations in light intensity over time. Such variations are often periodic, occurring at a specific frequency (but not always), and are caused by the driver of the luminaires. The degree of visibility and/or perceived irritation depends upon the frequency, modulation depth (ratio between maximum and minimum), and the shape of the modulation wave. A square wave with 100% modulation is more troubling compared to a sine wave with similar modulation (31, 33); see Figure 10. If the frequency is so high that the flicker cannot be detected visually, it is sometimes referred to as non-visual or subliminal flicker. In these guidelines, we will use the term 'flicker' to refer to visual flicker, and 'non-visual flicker' for frequencies that are not visible to the eye but that may affect the brain (see fact box for detailed definitions of the terms regarding flicker). The term 'modulation' will be used in the sense of light intensity variation. Both visual and non-visual flicker are common occurrences in LED luminaires and are caused by their drivers.

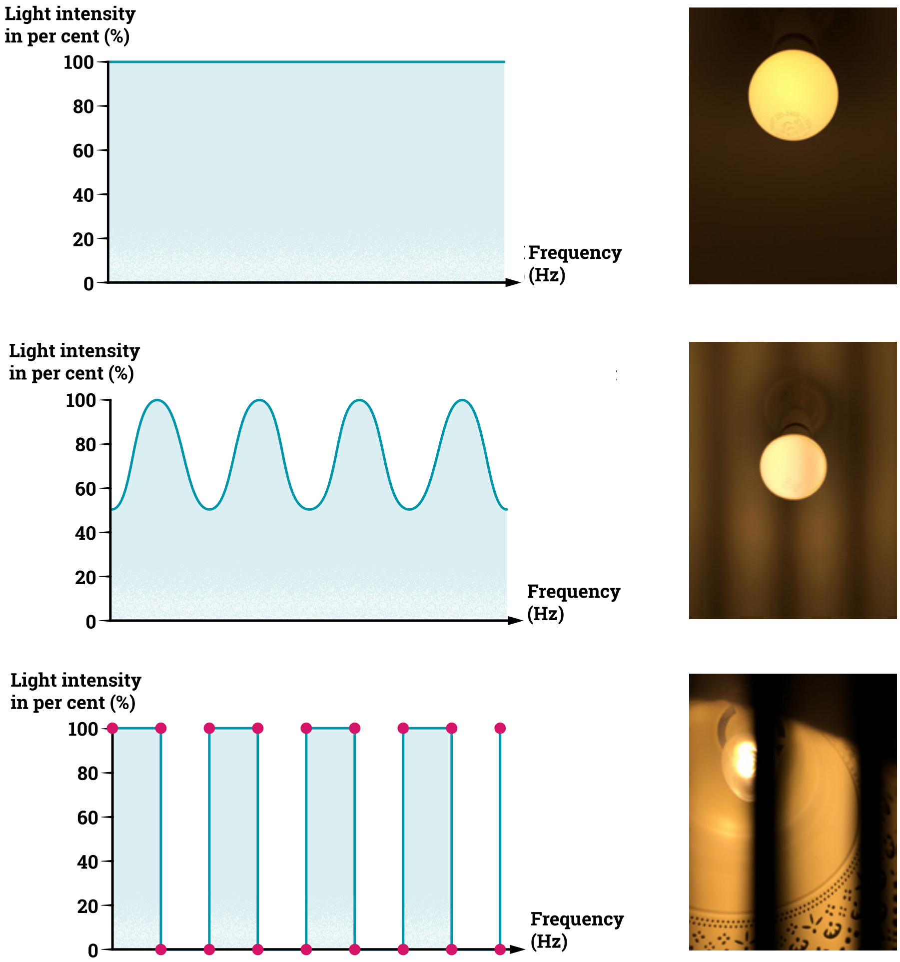


Figure 10. Modulation waveforms for different light sources with different modulation depths. Ideal 'waveform' (top), sine wave (middle), and square wave (bottom). The square waveform gives rise to a dark striped pattern when photographed with a smartphone (bottom right).

Flicker can distract and give rise to physiological effects such as headache and eyestrain, as well as effects on performance capacity. Because flicker cannot always be seen, these problems may incorrectly be presumed to be due to other causes, such as electromagnetic fields from luminaires or screens (31).

Light modulation at a frequency of 100 Hz will probably have no effect if the modulation depth is less than 8%. If the modulation depth is 35–45%, certain individuals will start to react (31). If the modulation depth is 100%, visible effects will be perceived during eye movements (phantom array effects) up to frequencies of 1 900 Hertz (34). Sensitive individuals can perceive these effects at frequencies as high as 11 000 Hertz (102). A *phantom array effect* is a light artefact, and refers to the dot shaped light trails of the light source that can be observed during the short time when eye movement is occurring (34).

Stroboscopic effects are another light artefact and refer to the visible effects that can arise when an object moves or rotates in the light from light sources whose light is modulating or flickering. Stroboscopic effects can also arise if the light source itself is moving. Rotating or moving machine parts combined with flicker can lead to dangerous situations. Moving machine parts may be perceived as standing still, rotating more slowly or in the opposite direction if the light modulation is close to the frequency of the moving machine parts. This can, e.g. in work involving a lathe, lead to carelessness and cause accidents (103, 104).

Pulse width modulation (PWM) is a dimming technique in which light modulation is introduced intentionally. The principle underlying PWM is that the light is rapidly turned on and off at high frequency. The dimming level is adjusted by varying the time the light is turned off and on, i.e. by modulating the *width* of the *pulse.* Any use of PWM increases the risk of visual and/or non-visual flicker and other light artefacts. Dimming technology that employs so-called amplitude modulation is preferable, as it does not introduce any light modulation at all.

Recommended frequency for LED light sources

The use of drivers with the highest possible frequency or completely frequency-free drivers is recommend to prevent problems with temporal light modulations and flicker. The *Institute of Electrical and Electronics Engineers* (IEEE) has issued a report, IEEE 1789 (31), in which they recommend a frequency of at least 1 200 Hz for LED light sources with 100% modulation. If these light sources are dimmed by means of pulse width modulation, the modulation will be affected, and the effects may be made worse. Stroboscopic effects are perceptible at up to 10 000 Hz when the modulation is 100% (105).

Flicker-free drivers that have frequencies above 20 000 Hz are available, or which are entirely frequency-free and emit a constant light. LEDs can also emit stable light if they are dimmed by lowering the amplitude of the direct current driving the light source rather than by chopping up the light via pulse width modulation. Some light sources change colour when they are dimmed using amplitude reduction, particularly at low light levels. Sometimes a combination is used, i.e. amplitude reduction down to ca. 30% of the maximum level and then pulse width modulation below 30%. Flicker is less troubling at such low light intensities.

At present there are only two measurement standards for measuring the effects of light modulation, i.e. PstLM for *flicker* and *Stroboscopic Visibility Measure* (SVM) for stroboscopic effects. Unfortunately, there is as yet no metric for the neurological and cognitive effects, but the risk of such effects is lowered if the PstLM and SVM values are kept low. Directives from the European Union does, however, allow PstLM below 1.0, and SVM below 0.4. A value of 1 means that the effects are visible in 50% of all cases for a standard observer. It has therefore there been seriously questioned why anyone should be bothered by light modulation when stable, modulation-free light sources are available for the same prices (106).

About flicker

The way in which the term *flicker* is used in these guidelines differs from its strict scientific definition. In the guidelines, the term flicker is used as a synonym for light intensity variations per se. The actual definition is that flicker is an artefact which can be seen when light varies in intensity over time. Whether flicker is perceptible depends upon several factors, the frequency of the variation, the modulation depth, the light level, general conditions, etc. The correct term for light intensity variations is *temporal light modulation,* where the word *temporal* indicates that the variation occurs over *time*. One of the reasons for not using this terminology in these guidelines is that, in an anatomical context, the word *temporal* can refer to something having to do with one's temples (i.e. side of head).

Temporal light modulation can in turn give rise to *temporal light artefacts,* i.e. *flicker, stroboscopic effects and phantom array effects.* Flicker refers to light variations that can be seen without movement of the eyes or the light source. For this reason, flicker is visible only if the light intensity varies at a frequency below ca. 80 Hertz. Stroboscopic effects are artefacts that can be seen if something is moving in light that is modulating, or if a modulating light source is itself moving. The effects can arise at frequencies between 80 and 2 000 Hertz. *Phantom array effects* refer to the artefacts that can arise during the brief time in which eye movement occurs, and are the punctiliar light trails from the light source that can be observed.

Temporal light artefacts are observable by definition, but it has also been shown that temporal light modulation can give rise to non-observable effects, such as headache, migraine or eyestrain. They can also affect cognitive performance and reading speed. These neurological and cognitive effects are presumably more serious than the visual temporal light artefacts, as individuals affected by them do not always necessarily perceive or understand that it is the light itself that is causing the problems (31, 33, 34, 102-105).

Job task design and visibility

In addition to light and lighting, the design and visibility of a job task also affects our visual performance capacity and the visual working environment. Each job task must be designed so that it is easy to see, and its visibility in relation to its surroundings must be high. Standard 'EN 12464-1' (2) or 'ISO 8995-1' (1) provides that visual and ergonomics parameters that can affect visual performance comprise:

- the design of the task (size, shape, position, contrast, chromatic and reflective properties of details and background)
- intentionally improved and planned lighting environment, glare-free lighting, good colour rendering, good contrast, and correction of any vision impairments can improve visibility and the sense of orientation and locality.

Visually demanding work is when the eye must be strained in order to see clearly. It can involve computer work in which multiple viewing screens are viewed with an upward gaze, work at an advanced control panel, or normal computer work in which the eyes have to converge and/or accommodate. It can also be inspection work that imposes heavy demands in terms of small details, or work done in poor illuminance or with glare from luminaires.

Computer work – a visually demanding job

It is currently common to find more than one screen at a workstation. In many cases there are two large screens, or one large 'wide screen' and, potentially, one or more additional screens. This can cause problems in terms of the working distance and gaze angles, and may cause improper working postures (1) entailing major twisting of the neck, which can contribute to increased musculoskeletal symptoms. The screens should preferably be of the same size and placed at the same height and distance. However, there are currently no known recommendations for how we should manage distances and gaze angles when we have more than one screen, larger screens (e.g. 26 inches or more), or curved screens.

Things to consider in connection with computer work:

- Luminaires that are positioned so that they can be reflected in a screen should not have a luminance above 1 500 cd/m^2 if the screen luminance (brightness) is less than or equal to 200 cd/m^2. If the screen luminance is higher than 200 cd/m^2 the maximum luminaire luminance that can be visible in the screen is 3000 cd/m^2 (2).
- The frame surrounding the screen (bezel) should not be too dark or too light, as that can give rise to contrast glare between the active screen area and the frame (107), nor should the keyboard be high-gloss or too light or dark. Screens should not be high gloss, as that can result in reflections from the surroundings. Read more in 'AFS 2023:11' which concerns work equipment and PPE.

- Desks and furniture should be brightly coloured, but not white or black. According to 'SS-EN 12464-1' (2), the reflectance from the most important items (furniture, machines, etc.) should fall in the range of 0.2–0.7, which corresponds to light wood colours or pale colours, such as light grey.

Most computer programmes currently use positive polarity, i.e. a light background and dark text. This leads to fewer problems than negative polarity (a dark background and light text). The keyboard should then also have positive polarity. Read more in 'AFS 2023:11'.

The distance to the screen must be adapted to the size of the screen(s); see Table 4. Depending upon the viewing distance, the character height should be adjusted so that it works well with the distance and the screen size used; see Table 5.

Table 4. Recommended distances for different screen sizes. Applies får single screen (4:3 CRT). Source: (68).

Screen (inches)	Viewing distance (cm)
15	52
17	59
20	69
22	76
24	83

Table 5. Recommended character heights for comfortable reading at different viewing distances. Applies for single screen. Source: (68).

Viewing distance (cm)	Character height (mm)
30	1.7
40	2.3
50	2.9
60	3.5
70	4.1
80	4.7
90	5.2
100	5.8
110	6.3

Display screens should be positioned heightwise so that the gaze angle to the centre of the screen is roughly 15–30° from the horizontal line, but it differs between different research publications; see Figure 11 (108-110). When having the top of the screen at or above eye level the amount of visual strain increased compared to having it below the eye level (111). For bigger screens, it usually means that the upper edge of the screen is roughly at eye level when the user is looking straight ahead. If the screen stand does not permit the screen to be lowered as much as is needed, a screen stand can be recommended that can be lowered down to the table surface, something that should be included as standard in all screen purchases.

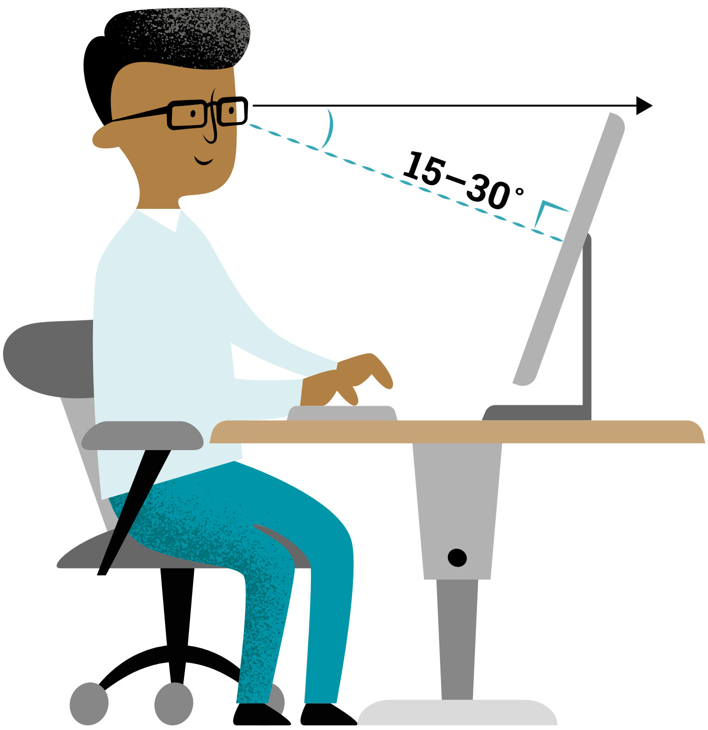


Figure 11. Position the screen vertically so that a viewing angle of approximately 15-30 degrees below the horizontal plane aligns with the centre of the screen.

Important to consider when procuring and purchasing display screens

- The screens must be adjustable in height so that the bottom edge can be positioned low, preferably down to the table surface but at most 5 cm above it.
- Screens must be tiltable from -5° to +20° relative to vertical.
- The frame around the screen (bezel) must be as thin as possible, and have a matte colour scheme (e.g. light grey or beige).
- The keyboard must have a matte colour scheme, preferably light grey with black characters.
- The screen surface should be matte to minimise reflections and glare.
- The characters must have good resolution and sharp edges.
- The screen brightness must be individually adjustable. This can be done using the *'brightness'* setting on the screen. Some screens adjust brightness automatically based on the surroundings *(adaptive luminance. control)*.

Other visually demanding work

The work object should be designed so that its contrast with the background affords good visibility. The ratio between the viewed object and the background must be at least 3:1 but not higher than 10:1. Inspection work is one example of extremely visually demanding work. Tables 6 and 7 offer recommendations for the distances that should be used. Lighting recommendations for such work are found in EN 12464-1 (2) or ISO 8995-1 (1).

Table 6. Recommended distances in relation to work object's smallest detail as per Weston 1962, Sight Light and Work for sound visual acuity of 1.0. (112)

Viewing distance (cm)	Minimum size of detail (mm)
50	0.1
60	0.16
70	0.19
80	0.20
90	0.22
100	0.25

Table 7. Character height for text can be calculated as distance in millimetres/200 = character height in millimetres. Applies to both signs and screens (68).

Viewing distance (cm)	Character height (mm)
30	1.5
40	2.0
50	2.5
60	3.0
70	3.5
80	4.0
90	4.5
100	5.0
200	10.0
400	20,0
600	30,0

Visual function of the eye – common vision impairments and different types of glasses lenses

There are different types of vision impairments, i.e. **farsightedness** (hyperopia) and **nearsightedness** (myopia), sometimes in combination with **astigmatism**, which is also sometimes called refractive error. In hyperopia the eye is too weakly refractive, or too short, and a plus lens is then needed to refract the beams more. With myopia the eye is too refractive, or too elongated; the beams need to be split more, and a minus lens is needed. Astigmatism is caused by the eye being ovoid rather than being spherical, i.e. more rounded in one direction and flatter in the other. This results in two focal distances, and the image becomes blurred. A person with astigmatism who looks at a circle sees a smeared or partly doubled oval, with a shadow behind it. Figure 12 shows refractive errors and how they are corrected. (113)

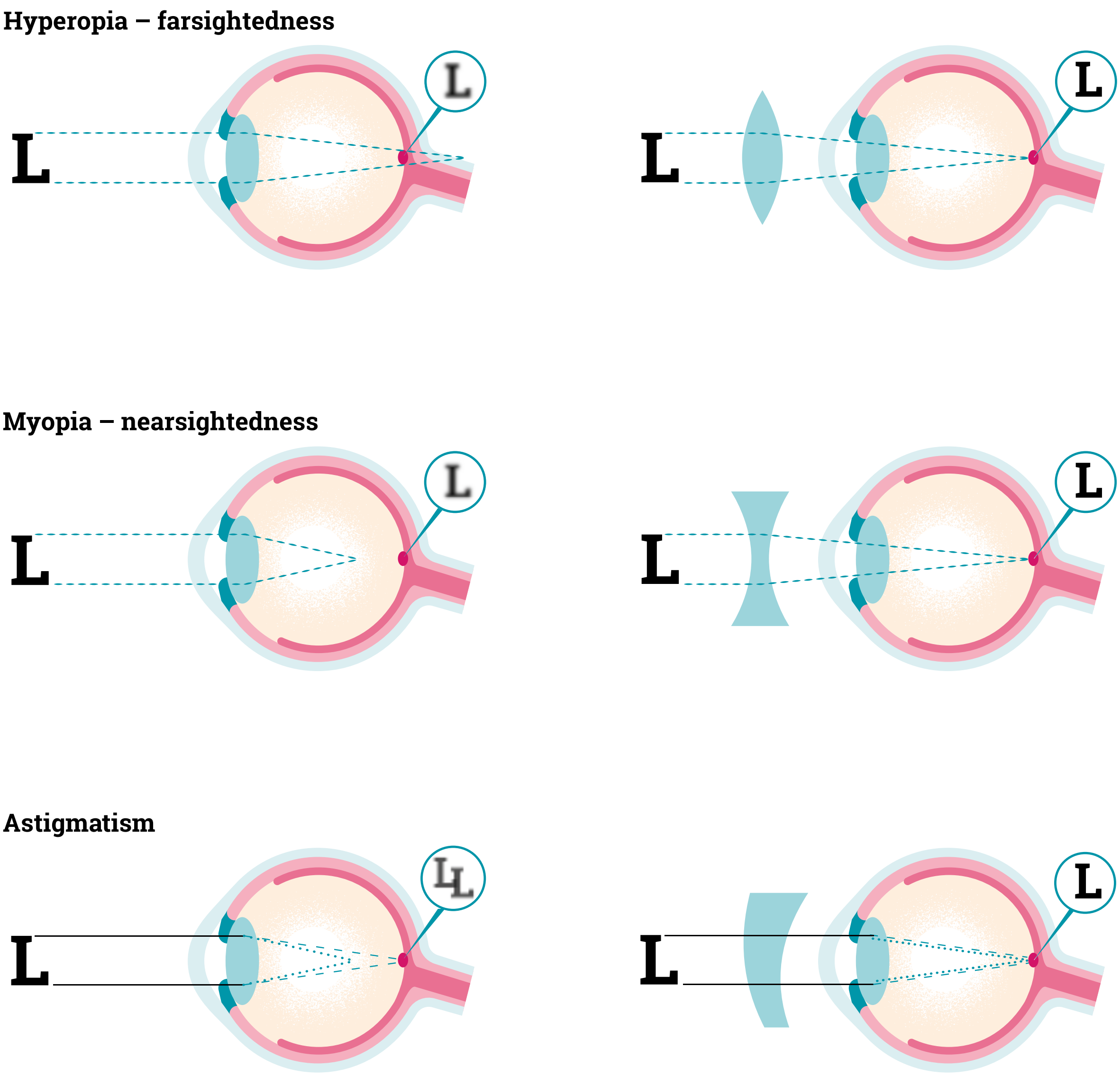


Figure 12. Different types of vision impairments and how they are corrected.

Glasses filters and lens treatments

Glasses can be treated in various ways to enhance visual comfort. Anti-reflection treatments are useful, as they reduce the risk of glare and reflections in the lens, and provide better sight (114). There are also various types of tints and filters that can facilitate the sight of those who are more sensitive. One example is migraine filters, which usually have an orange colour that makes things feel more comfortable, and they can reduce the symptoms and incidence of migraines (35, 115). Glasses with blue light filters are currently available that are claimed to reduce computer-related visual symptoms. These recommendations lack a scientific basis (114, 116). Such problems are often due to the screen being set too bright. The blue light has many positive effects on our circadian rhythm and degree of alertness, and blue light filters should consequently not be used on glasses at indoor work.

Work glasses

In some countries employees are entitled to glasses paid for by their employer if their own glasses are ineffective for the working distances and/or the job tasks they face. This is established in 'AFS 2023:11' which concerns work equipment and PPE. One is entitled to protective eyewear if the job poses a risk of damage to one's own glasses, or a risk of eye damage. There are numerous different types of lenses to choose from. It is up to the optician to determine which type of lens best suits the job task in question.

Occupations that entail problematic working postures involving extensive forward inclination of the head to view the work object can lead to musculoskeletal disorders. Dentists and dental hygienists are such occupational groups. They often work with their heads tilted heavily forward, which can cause neck problems. The stress on the neck can be reduced by using so-called prism lenses or loupe glasses, the effect of which is to reduce forward bending of the neck. The prismatic effects cause the image to be shifted to a different plane, which significantly decreases the need to bend the neck forward (117). The opposite situation, with a marked upward gaze and the head tilted back, can also give rise to problems. Examples of such occupational groups include electricians, aircraft pilots, and vehicle inspectors.

Work glasses for visually demanding work are important to ensure good performance during the workday in individuals who need them. Good correction for close-up work facilitates performance and enables a better working posture and fewer problems with eye complaints and headache. Such glasses are available in many different variants and are intended to correct different types, degrees and combinations of vision impairments, and are used for different types of work; see Figure 13.

- **Distance lenses** – single-power lenses, used to see clearly from far away.
- **Reading lenses** – single-power lenses, used to be able to see clearly close up or at computer distance, typically the first work glasses one gets.

- **Progressive lenses** – multi-power lenses, with several different zones for various distances. At the top there is a section for longer distances, while below there is a section for reading, and in between is a transition zone with all the intermediate powers. Such lenses are unsuited for computer work, as the reading section is located too far down and the middle section is too narrow and also too far down, which causes one to lift the chin and bend the neck back.
- **Bifocal lenses** – multi-power lenses with two (sometimes three) different powers. There are one or two reading segments at the bottom of the lens, while the rest of the lens is for distance vision.
- **Room-progressive lenses** – multi-power lenses adapted for close-up work, e.g. computer work. Looking straight ahead there is a zone for roughly 70–80 cm, at the bottom a zone with reading power, and at the top of the lens an area for room space (ca. 3–4 metres, depending upon lenses and power).
- **Near-progressive lenses** – multi-power lenses with two zones for close-up work, e.g. computer work. Looking straight ahead there is a zone for ca. 70 – 80 cm, plus a zone of reading power at the bottom.

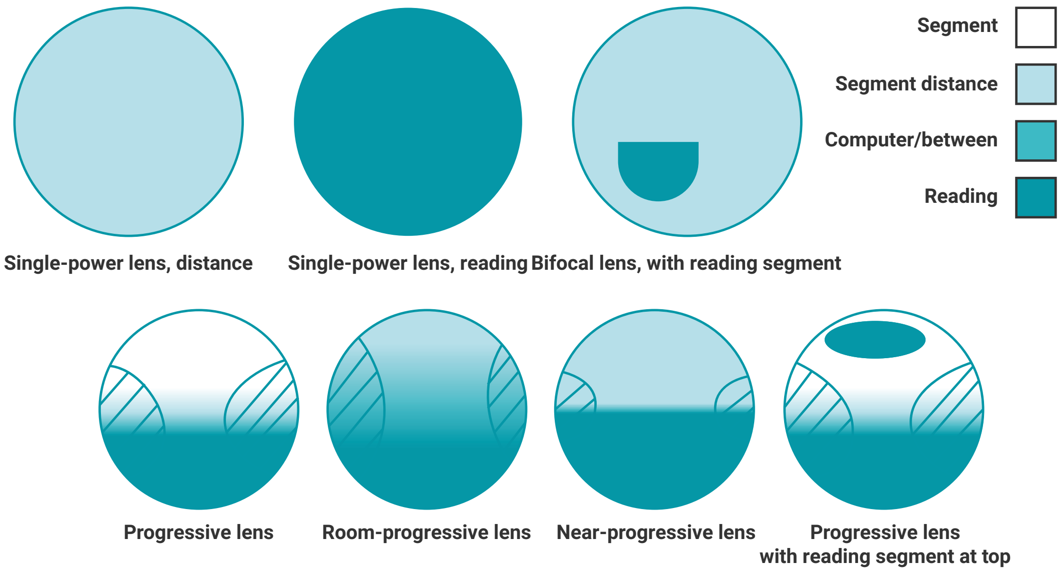


Figure 13. Different types of lenses. The strengths change, i.e. the more addition as indicated by the darker the blue colour. The striped areas in the lenses are so-called distortion fields, in which the image may be perceived as blurry. This occurs because there are so many different powers in the lens.

When a person has vision problems or subjective complaints such as visual symptoms, problems with their upper extremities or headache/migraine, they should be given a requisition to undergo a vision test. According to Swedish regulation 'AFS 2023:11', the emloyeer must bear the cost of vision testing and, if necessary, the cost of the vision aids needed if the employee works at a computer for an average of one hour or more per day. Read more about vision tests and work glasses in the chapter entitled *Visual Ergonomics in Systematic Work Environment Management,* page 61.

Planning of lighting and visual ergonomics in new construction, renovation and extension

This chapter discusses the planning and engineering of lighting and visual ergonomics in connection with the new construction, renovation of and extensions to facilities and workplaces. The most options are available during the planning stage, and the choices made then will have the greatest impact on the work environment, at the same time as the procurement and total costs of the chosen solutions can be kept low. During planning it is possible to minimise the system costs while at the same time achieving good visual ergonomics and lighting that contributes to high operational quality, productivity and sustainability. This chapter offers work processes, flow diagrams, ways of working, checklists and templates that can facilitate the planning of new or altered facilities. The methods and ways of working are intended primarily for Occupational Health Services workers or actors with similar expertise. The chapter can also provide employers with support in decision-making, financial calculations, and procurements. Safety representatives and individuals with work environment responsibilities can also derive support in creating proper and sustainable visual ergonomics.

The role of Occupational Health Services and work environment consultants in the planning process

Client companies will derive optimum benefit from Occupational Health Services and other work environment consultants if such resources are engaged early in the planning process, as the opportunities available to create functional and cost-effective solutions are greatest then. This can be natural for in-house Occupational Health Services, but it is not always easy for outside occupational health experts or other work environment experts to become involved in the planning process early on.

Schmidt (118) showed in her PhD thesis that Occupational Health Services work best when there is trust and positive, long-term dialogue between the occupational health staff and their clients. It is crucial in such dialogues that the client companies provide notice of any upcoming changes, and that they are aware that Occupational Health Services offers services pertaining to preventive work environment measures in the planning stage. Such mutual dialogue and the systematic assessment of implemented remedial measures create opportunities to enhance the knowledge and experience of both parties. It is also clearly important for Occupational Health Services to offer services in the areas of visual ergonomics and lighting, to remind clients of this, and to seek information when client organisations are planning new construction, or renovation of or extensions to their facilities and workplaces. It is also important for Occupational Health Services to continue to develop their competence and gain more experience by participating in the planning of visual ergonomics and lighting. The expert knowledge that Occupational Health Services can contribute includes, in addition to knowledge about visual ergonomics and lighting, knowledge about the work environment, job requirements, workplace design, the properties of the workspace and knowledge about the employees, i.e. knowledge that is important in planning the lighting. Occupational Health Services or experts with similar competence can contribute to some steps in the planning process, while in others they can contribute expert knowledge and collaborate with the responsible parties. They can then, for example, facilitate communication between client and actors in the planning process, and generate a factual basis for decision making. Examples of ways in which Occupational Health Services have developed their roles in planning processes are provided in Broberg and Hermund (119), and in Seim and Broberg (120).

The planning process

The planning process can be organised in different ways and should be tailored to the situation in question. This chapter describes and offers examples with two common typical cases. One case involves a comprehensive planning process for the new construction of a large facility, while the other involves the planning for a minor renovation of an existing facility; see Figure 14. The steps involved are described in detail in the text.

Occupational Health Services or actors with similar competence can, for example, create planning documentation regarding visual working environment, needs identification, activity mapping, workplace analysis and requirement specifications, as well as reviewing the formulated proposals. They can also provide support to those connection with handover, operation, maintenance and final responsible for procurement and purchasing, and contribute in connection with handover, operation, maintenance and final evaluation.

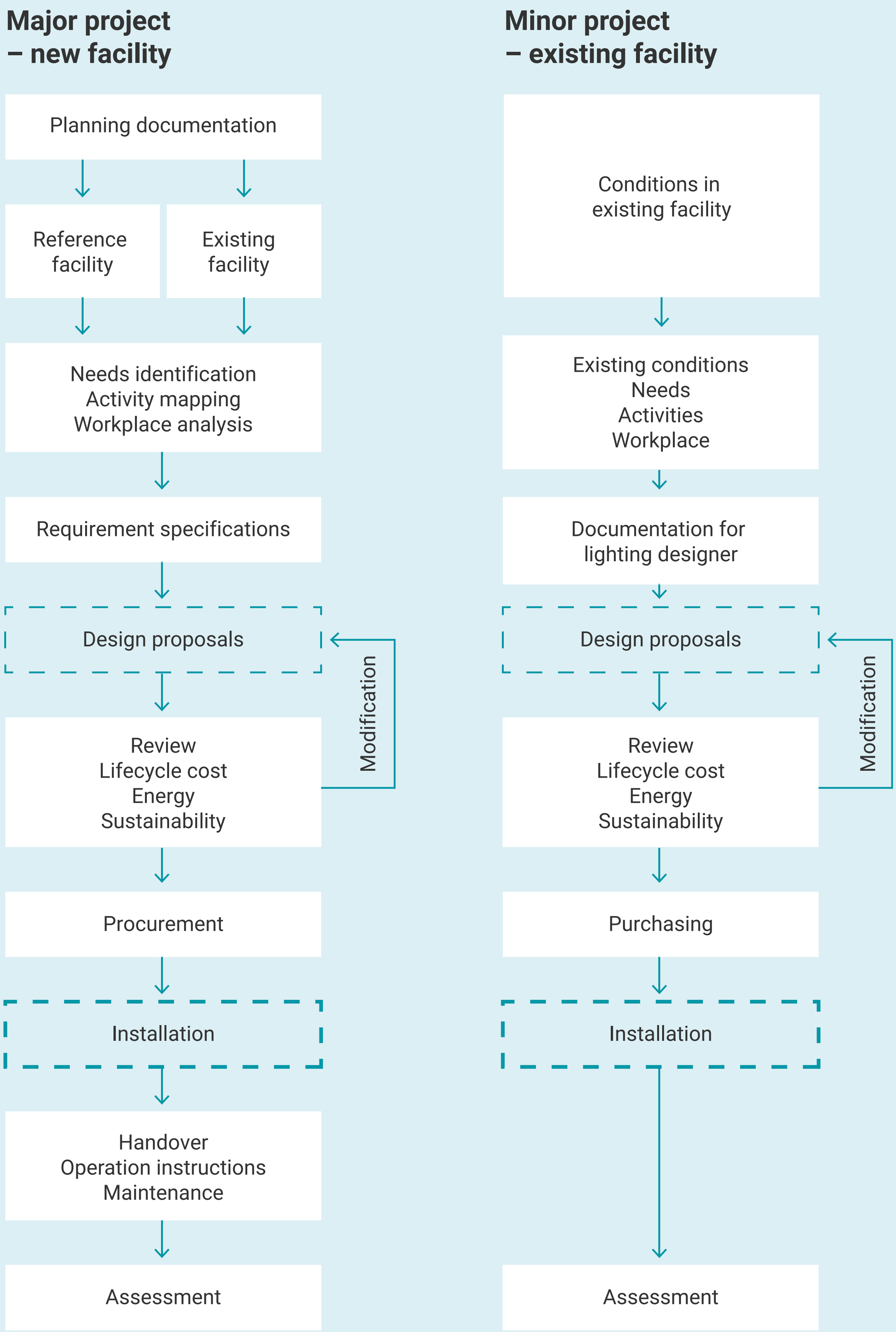


Figure 14. Two examples of planning processes. The process steps in which Occupational Health Services can make important contributions are filled in. The broken-line boxes indicate process steps that are carried out by other actors.

Planning documentation

The first step is to describe the settings for the new construction, renovation or extension. Here, **needs identification, activity mapping** and **workplace analysis** are carried out as the basis for planning the visual ergonomics and lighting. This should be done as early on as possible, and preferably before the planning begins. Employee experience provides a starting point that should be considered. Several of the methods used at this stage are consequently participatory, i.e. the affected individuals and functions are allowed to take part. This analysis can often use the old or existing facility as a foundation for amassing experience, and as a documentary basis for the planning. No such facility will be available in some cases. It is then possible to build on experience from a similar one, i.e. a reference situation (121).

A reference situation may consist of a facility that houses similar operations from which one can learn, either within or outside the organisation, perhaps abroad. A great deal can be observed in the reference facility, such as typical work activities, workplace designs, visual requirements, lighting, visual ergonomics measures and so on. Requirement specifications for the lighting may be available. It is possible, based on the planned operations and the operations in the reference facility, to derive an idea of the future work activities, workplaces and visual requirements. An assessment should also be made as to whether the design proposals are relevant in view of these presumed future work activities, or whether anything needs to be modified. If there are no existing facilities or reference facilities, one must proceed based on the planned workplaces and work activities.

Needs identification

Prior to planning the visual ergonomics and lighting, it is key to determine the needs that the various employees have if they are to be able to perform their work tasks efficiently.

Needs identification is a method of determining what the users need for their work (122). It is not about solutions, but rather needs and desires. The needs in terms of visual ergonomics, light and lighting are collected via observations and interviews. The method has four steps, which the responsible party follows when collecting information at the existing facility or from the reference facility:

1. **Frame and prepare**
   Define targets and the target group, what is to be observed, which individuals will be included, and which questions will be posed. This also includes literature studies.
2. **Observe and document**
   Visit the workplace, observe the work and what goes on there, observe the workplace, record videos, take photographs, make measurements and take notes.

3. **Interview and document**
   Conduct individual or group interviews in the workplace. Record the interviews and make notes. Ask for explanations and clarifications, and about what is working well, problems, and desires.
4. **Interpret and reformulate**
   Interpret the material and rewrite it from a needs perspective. What desires exist, and what can be corrected so that the work can be performed easily, quickly and properly?

During the process, it is a good idea to relate the needs to what is required for the various tasks to work well for the employees, but also for them to be done quickly and correctly. This four-step process identifies what is good and what one wishes to keep, while also highlighting desires in terms of how the new planned work situation can eliminate problems and make the work even easier to perform.

Activity mapping

Several methods are available for those situations in which data and experience are collected from reference facilities or existing facilities. The underlying principle is that work activities which involve visual tasks are mapped, and particularly those that are most important, most critical and demanding, and those that are performed for extended periods of time. Table 8 offers examples of elements that can be included in activity mapping. Here the participants handle the data collection themselves by recording, on a number of representative days, which activities they have been engaged in, and for how long, for each of their activities. Alternatively, the activities may be observed and documented by a third party.

A detailed description of how activities can be mapped is provided in Appendix 4.

Table 8. Examples of activity mapping.

Work activity	No. of activities performed	Breakdown by activity (%)
Assembly	27	57
Materials management	12	14
Quality control	10	9
Telephone conversation	8	8
Meetings	5	6
Staff meetings	3	3
Computer work	2	2
Delivery	2	1

Another method is to create so-called **workbooks**, in which employees are asked to highlight a number of typical work activities, with a focus on visually demanding tasks and lighting. These are photo-documented, and a workbook containing pictures from the photo-documentation process is then displayed in the workplace for several weeks, and the employees can draw on them, and comment on which work activities are working well and which could be improved, as well as offering ideas about how the work could be facilitated. A more detailed description of this method is provided in Appendix 5 (123).

Workplace analysis

The **photo-safari** method can be used on visits to reference facilities, other existing facilities, and in the existing facility in question. Pictures are taken in the selected facility, and different coloured pens can be used to draw on them and make comments, e.g. green to indicate what is good and should be kept, or red to show what is not working well and needs to be improved. This method is described in greater detail in Appendix 6 (123).

Yet another method for analysing workplaces in existing facilities is the **improvement log**. All employees are invited to report problems and opportunities for improvement over one to two weeks. The important thing is that this should be done as soon as one becomes aware of the problem or improvement opportunity. This can be done by leaving a message on an answering machine, via SMS, mobile phone photos, e-mail, a website, physical letters, or via the regular deviation system, if applicable. A more detailed description of this method is provided in Appendix 7 (123).

The existing facility or reference facility can also be analysed with the help of the *Detailed checklist for lighting/visual ergonomics,* which is intended for individuals with specialist knowledge. The checklist covers various aspects of the workplace, work tasks, visual requirements, lighting, daylight, maintenance and display screens, and is found in *Vision and lighting in working life* (68)(1), a translated version can be found in Appendix 17.

Requirement specifications (major project)

There is often a large project team associated with major new construction or renovation, one that includes architects, lighting consultants and electrical consultants. The role of the Occupational Health Services in such cases may be to offer input to such actors regarding work activities, work environment requirements, needs, and workplace requirements. Project supervisors must sometimes clarify the thinking behind such new construction and work designs so that Occupational Health Services can provide its perspectives.

One effective way of working is through requirement specifications for lighting and visual ergonomics. The developer/designer will often be grateful for appropriate requirements, so that they can then decide which requirements are to be set in their requirement specifications. This approach creates a clear starting point for the planning, and for the subcontractors. Such requirements specifications exist for various enterprises, such as offices, healthcare facilities, and industry. Appendices 8 and 9 offer examples of how requirement specifications for lighting can be formulated. Documentary basis for lighting designers (minor projects).

Occupational Health Services and actors with similar expertise can facilitate the limited renovation of existing facilities by providing visual ergonomics documentation and then contacting a lighting designer for a concrete lighting proposal for the client company. Some lighting companies and architectural agencies have a lighting designer on staff. They are trained in taking various factors into account, such as the layout of the facility, the means available to install luminaires, and the intended use of the facility. The work activities, spaces and who will be working there are utterly decisive in terms of what types of luminaires and light distribution are to be used. For example, protection-rated/IP (Ingress Protection)-rated luminaires may be required for humid environments or if special materials are present that need to be washed often, including in healthcare applications. For a lighting designer to be able to propose a lighting solution, the documentation must be as detailed as possible.

It may take time to determine the reflections from various surfaces, but this information is very important for the visual ergonomics in the facility. This includes both the relationships between various surfaces such as floors, ceilings and walls, and the choice of lighting solution. A light meter, such as a Hagner ScreenMaster, can be used in an existing facility to measure the actual reflections from various surfaces, or to measure reflections from proposed colour samples for the planned facility.

- Measurements and calculations of reflection factors are described in Appendix 10.
- Definitions of terms are found in Appendix 1.

Documentation sought by lighting designers and planners

- Activity on premises, work activities
- Room type
- Room length
- Room width
- Room ceiling height
- Ceiling colour/desired reflection (%)
- Colours on walls/ desired reflection (%)
- Floor colour/desired reflection (%)
- Colour temperature
- Illuminance [lx]
- Luminance [cd/m²]
- Need for screening Room temperature
- IP rating
- Current luminaires
- Desires for luminaires
- Type of technology/ control/ monitoring/ light regulation/ sensors
- Installation height
- How installed/ limitations
- Existing installation and mounting points, e.g. existing lines.
- Installation method

Review of lighting proposals and drawings

Proposed drawings of new lighting systems are often produced by lighting designers, lighting consultants, architects, and electrical consultants. See the following checklist for questions that Occupational Health Services can use in reviewing and offering views on such proposals and discussing them with those who have proposed them, i.e. designers and suppliers.

In cases where the lighting proposal is based on a requirement specification, the requirement specification can be reviewed.

Checklist for reviewing proposed drawings for lighting systems

Translated and modified from *Vision and lighting in work life (68)*

- Is the lighting tailored to each and every one of the planned workstations? How?
- Has the lighting been tailored to the particularly visually demanding tasks that will be present? How?
- Has the lighting been adapted for an older workforce? How?
- What lighting levels are present at the individual workstations, and in the immediate and outer surroundings?
- Can the illuminance be adjusted easily? How, and between what levels?
- What luminance distribution has been planned for the individual workstations?
- In what directions is the light planned to be directed in relation to gaze directions?
- Is there indirect light in combination with direct light?
- Is there good access to daylight and views? Can disturbing daylight be screened off easily?
- How well protected are the luminaires and light sources from glare?
- Is there a risk of other glare, reflections, or unfavourable shadows?
- Is the lighting system designed so that the light sources do not emit visual or non-visual flicker?
- What light colours and colour rendering do the proposed light sources exhibit?
- What reflectance and colouration are present in surfaces on the premises, i.e. ceilings, walls, floors, desks, equipment, and machinery?
- How has the lighting in common areas (corridors, staff rooms, etc.) been planned?
- Can the lighting system be cleaned and maintained easily? Is there a maintenance plan?
- Are all official requirements met? Which protective, energy, environmental, work environment and safety requirements have been taken into account?
- How is the emergency lighting planned?
- Is it possible to test-hang luminaires and create a small test area (mock-up)?

If there has been no opportunity to set clear 'shall' requirements, then other means of review and assessment can be used. This enables work environment-related aspects to become a key decision-making criterion.

The assessment can be made by:

- using a local test panel in which a number of individuals within the organisation take part and test/rate the various lighting products before a decision is made
- creating a test room or demonstration room in which luminaires can be test-hung in order to see how the various products function in practice, and to evaluate them based on a predetermined protocol
- create a 'mock-up' (simple prototype) in which the system's functionality and usability, control system and interfaces can be tested, thereby obtaining user feedback on such aspects.

It is possible to review proposed lighting in a room or space with the help of a software program, DIALux Evo, which is available for download free of charge. Instructions and support for its use are available on the program's website.
In many projects, multiple solutions will have been gathered in, so that the solutions of the various suppliers can be assessed and reviewed. The assessments and reviews can lead to a lighting proposal needing to be modified by the party who submitted the proposal.

Lifecycle costs, energy, and sustainability

The environment, energy and costs are important factors when planning a lighting system. Energy costs account for a large share of a system's costs throughout its lifecycle. One strong argument for a new and well-designed lighting system is that it will save energy and, in turn, operating costs, while at the same time offering better visual ergonomics, which contribute to better quality, productivity, and employee health.

There is a simplified formula for calculating lifecycle costs:
LCC = PA + PE × UEA × T + EOL

LCC – *Lifecycle Cost*

PA – *Cost of luminaires and installation*

PE – *The price of energy*

UEA – *Annual energy usage*

T – *Number of years the system will be used*

EOL – *Scrapping costs*

A more in-depth model, the Life-Cycle Costing *(LCC) calculation tools* has been developed by the EU. The model can be used for indoor as well as outdoor lighting. It calculates the total cost, energy consumption, environmental impact, etc. The energy costs are an important factor in calculating the total cost of a lighting system. The calculation tool covers energy consumption as well as energy costs, and it can also calculate CO2 emissions for the lighting systems. Note that one cannot use the benchmark 'energy consumption per lux' alone, as that benchmark rewards luminaires that are poorly glare-proofed. A low level of glare is, after all, one of the most important visual ergonomics criteria; see the section on Glare, luminance distribution and luminance ratio in the chapter entitled The workplace's visual environment.

One alternative when it comes to financial calculations of work environment equipment is to use the system cost. Here we illustrate the various costs for a workplace in the enterprise to function. To ensure that the example is comprehensible, we have calculated the costs per hour over the service life of the product or system. The method is illustrated in Table 9 using an example of an electronics assembly workplace. The cost types addressed comprise payroll costs, including overhead, facility costs, consumable materials, and workplace lighting.

Table 9. Example showing principles of system-cost calculation using production data (83).

Cost type	Cheapest luminaire	Visually ergonomic luminaire
Payroll costs	25 Euro/hour	25 Euro/hour
Facilities cost	1 Euro/hour	1 Euro/hour
Consumable materials	0.5 Euro/hour	0.5 Euro/hour
Lighting system (cost of purchase, installation, operation and maintenance)	0.1 Euro/hour	0.15 Euro/hour
System cost (total of the foregoing costs)	26.6 Euro/hour	26.65 Euro/hour
Production volume	97 units	100 units
System cost/unit	0.2742 Euro/unit	0.2665 Euro/unit

The total cost (luminaires purchases, installation, operation/energy and maintenance) of the visually ergonomic luminaires may be higher, but it need not always be so, compared to the total cost of a luminaire that is purchased based on the principle of cheapest purchase and installation. The example shows that the difference in cost between buying the cheapest luminaire and a good visually ergonomic luminaire is just a small fraction of the system cost. The decisive factor for the system cost is whether the productivity and quality of the performed work can be improved. Many studies in the overview by Juslén and Tenner (124) indicate that good lighting improves productivity and quality from several to several tens of per cent. A productivity difference of 3% is used in the case above, as per the study by Juslén et al. (83). At the same time, good lighting can also contribute to greater wellbeing, lower absenteeism due to illness, and lower staff turnover in the long run. Our conclusion is that the system cost will generally be lower if good lighting and visual ergonomics are achieved.

Procurement

Favourable opportunities for influencing the products purchased are present during the procurement process. Many major organisations with in-house Occupational Health Services have configured their purchasing processes so that the Occupational Health Services can contribute its views or sometimes even approve product choices before the decision to purchase is made.

There are different criteria which must be met, i.e. the organisation's own requirements level, regulations, and legal requirements. Procurements made by public sector enterprises in Sweden must also be based on the Swedish Public Procurement Act. Many countries have their specific rules for procurements. This statute makes it possible to incorporate quality requirements in the procurement process, including aesthetic, functional, and work environment-related aspects. Occupational Health Services can support their client organisations in formulating such quality requirements. The ways in which different tenders and products will be assessed must be incorporated early in the planning stage, as must the ways in which the transparency of the process will be ensured

The various roles in a procurement process must be clear. The procurer is the principal, but the planning supervisor also plays an important role. Users and Occupational Health Services or work environment consultants must become involved early on to ensure that work environment aspects are considered. Lighting planning is, as noted, affected by factors such as choices of materials in facilities, colouration and reflectance of walls, floors, ceilings, luminaires and fittings. Facility planning thus affects purchases of luminaires and fittings such as desks, equipment, and computers.

Appendix 11 describes in greater detail what the various planning stages encompass. There are also checklists and reference guides for factors that must be considered when purchasing workplace components, equipment, screens, computers, colouration, and so on. These are found in part in the TCO Certified Procurement Guide. Other examples of requirements that may be set in connection with procurements of display screens are found on page 41. More information about how to work to achieve good work environments in procurement processes can be found in the EU webpage on Green Public Procurement.

Handover, operating instructions and maintenance

Handover, operating instructions and maintenance are essential in every project, and experience shows that issues always arise that must be addressed. How should the employees be trained in operating the systems, how should the handover from the project to the operations proceed, how should the adjustments which are always needed in connection with placement into service be made, and what do the maintenance routines look like?

Handover

Different systems are often used at present to adjust lighting. The supplier needs to provide documentation for all of the system functions, digital solutions, and instructions for using them. There should also be documentation describing how the system is used, and the control systems it contains, as well as documentation concerning any modifications. Operating instructions should be available during the handover phase, as should a maintenance plan (see below). Relevant training should be proposed as well.

Operating instructions

Figure 15 shows an example of operating instructions from a classroom. These types of instructions are especially important when pre-programmed control and adjustment of the light is more complicated than just a simple on-off switch. Occupational Health Services can contribute by pointing out the need for this type of operating instructions, and can also take part in formulating them.

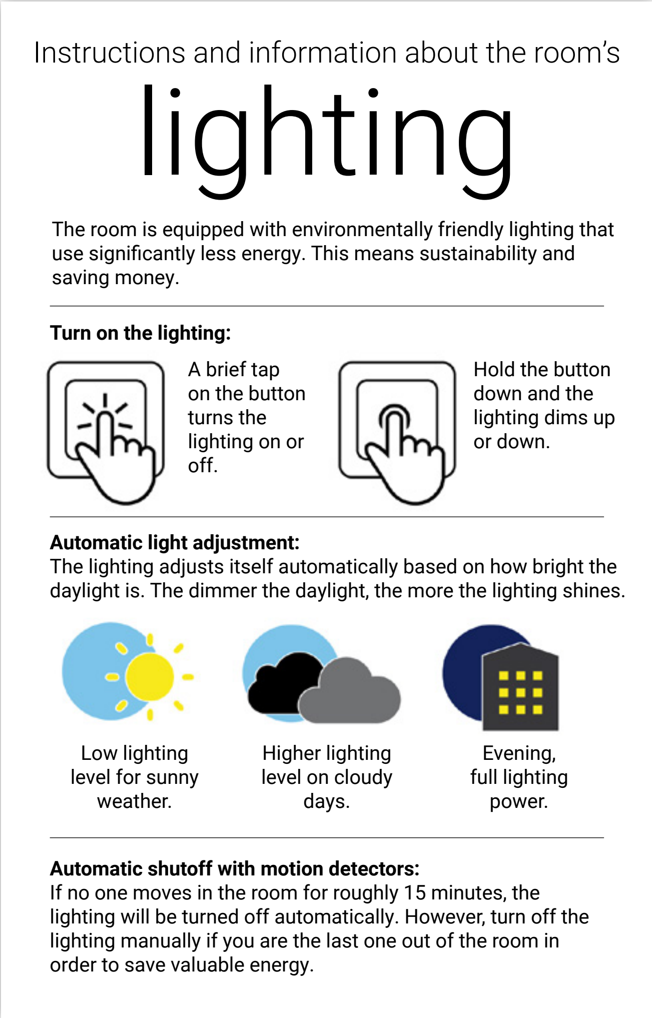


Figure 15. Example of operating instructions for classroom lighting.

Maintenance

The supplier should provide a maintenance plan for the lighting system. Scheduled maintenance in which all the light sources are replaced or cleaned simultaneously usually means lower costs and better lighting. The cleaning interval depends upon the degree of dirt build-up and how much the brightness decreases over time, and upon how much of the original illuminance one wishes to maintain. The maintenance factor (MF) indicates how much of the original illuminance remains over time. The decrease depends upon the following factors:

- light loss of the light source (LLMF)
- lamp loss when some of the light sources go out (LSF)
- luminaire cleanliness (LMF)
- room cleanliness (RSMF).

The formula for calculating the maintenance factor is:

MF = LLMF × LSF × LMF × RSMF

Assessment

It is essential to assess the implemented systems. This is part of the Systematic Work Environment Management, but also serves as a follow-up to the planning work and offers a learning opportunity ahead of future projects.

Once a lighting system is ready, it must be inspected. This is done by inspectors, who assess its technology, execution, and safety. Occupational Health Services can also assess the visual ergonomics based on the requirement specifications, and make sure that the specified system procured is correct. This means, for example, that the system's illuminance and uniformity, luminance ratios and glare can be assessed based on the set requirement specifications. A simpler form of employee interview can be conducted, or the workplace can be reviewed with the help of a method/checklist, preferably the *Detailed checklist for lighting/visual ergonomics.* Read more about checklists and methods in Appendix 13.

Rules and regulations concerning lighting planning

According to the Swedish Work Environment Authority's regulation, 'AFS 2023:12' which concerns workplace design; developers, designers and work environment, coordinators are responsible for creating an acceptable work environment for future users during the planning and design processes. This means that the work environment must be taken into consideration in the planning of both the construction phase and the use phase, and the regulations apply to all employees who can foreseeably be presumed to work in or in connection with the finished construction. Regulation 'AFS 2023:3', which concerns design and construction work environment coordination, also outlines the responsibilities during the planning and design phases, as well as the roles of the construction work environment coordinators. The European Union (EU) has also intensified its requirements in terms of energy use in its 'Energy Efficiency Directive' (106), which will expedite efforts to achieve more energy-efficient lighting.

Application: Lighting planning experience

Working in healthcare, offices and certain industrial applications entails heavy visual demands, as the job tasks there often involve inspection, reading, colour assessments and the interpretation of texts, figures, photographs or drawing documentation in hardcopy or on display screens. Improperly designed light can negatively affect both health and performance in such types of work. Major improvements in terms of occupational health, wellbeing and performance can be achieved by planning for proper lighting and visual ergonomics.

Communication with enterprise and corporate leadership in terms of how plans call for the future operations to be conducted is a precondition for creating good visual working environment. Such communication encompasses job tasks, facilities, equipment, luminaires and fittings, and potential changes in the operations. The Occupational Health Services knowledge of proper lighting and visual ergonomics can best be applied during the planning phase. At the same time, the added costs will be low if lighting that is appropriate for the working situation is planned for from the start. As a general rule, it costs roughly ten times as much to remedy a mistake after the fact than it does to do things properly from the start. Good visual ergonomics also improves job performance, i.e. the quality and productivity of the operations, which will also have positive financial effects.

The new construction or renovation of facilities is based on the planned operations, i.e. offices, industry, or healthcare. The facilities must be planned so that daylight is utilised to the greatest possible extent, via windows and other entry points for this light. New technologies, such as mirror arrangements, fibre optics, lighting shafts, etc. are being developed to bring more daylight into spaces. The colouration of ceilings, walls, floors, luminaires and fittings is also important in terms of light levels, luminance ratios and spatial perception. The sun creates both overly bright light and too much heat if it shines on workspaces directly. The situation and orientation of the building entails that, in some directions, direct sunlight must be screened off by means of outside sunshades, blinds or other types of screens. Dark glass windows and solar films are not appropriate, as they limit outdoor view.

During planning, decisions are also made regarding the principal conditions and assumptions for the lighting design, i.e. whether lights are to be positioned in relation to the individual workstations or if the entire space is to be lighted uniformly, so that the furnishings are flexible. If the requirements in terms of energy efficiency are pushed too far, i.e. so that the luminaires must provide as much light as possible relative to the energy consumed, there is a risk that the luminaires will produce glare. The use of display screens means that digital work stations must be positioned so that there are no windows or other entry points for intense light in front of or behind the screens. Workstations must be planned so that large numbers of people do not move about in the field of view, and so that the background is calm. It is also necessary to assess the solutions introduced, which is, of course, part of the Systematic Work Environment Management. Such assessments also offer a means of identifying opportunities for improvement and learning for everyone involved.

Visual ergonomics in Systematic Work Environment Management

This chapter describes how it is possible to work practically in investigating, risk-assessing, remedying and following up on visual working environment in such a way that it becomes a natural part of the Systematic Work Environment Management in the workplace. It also sheds light on the roles of the employer, the employee, and the expert. Employers are offered guidance in how the investigative work can be developed so as to prevent and detect deficiencies in time. Ways of working and methods for risk-assessing visual working environment are presented for experts working in occupational health or similar fields, as is support in proposing appropriate remedial measures.

The responsibility for working systematically to constantly improve general work environment conditions and avoid on-the-job risks rests with all employers, and is specified in Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work. It is especially important with respect to risks that can lead to injuries which could have significant and serious consequences for individuals and organisations. The investigation, assessment and improvement of the visual ergonomic working conditions in the workplace is an area in which many employers still lack knowledge, experience, and routines. This may be because the risks and consequences attributable to deficiencies in visual ergonomic design are less well known although severe health problems and even death can occur as consequence. The area is also complex, there are many factors which affect how a good visual environment should be designed.

Assessing risk in the visual environment and proposing satisfactory remedial measures requires expertise, i.e. an Occupational Health Services or other actor with expertise in the area of visual ergonomics. But there is also a great deal that the employer and employees can do themselves. This includes having key routines in place, as well as ensuring that visual ergonomics are incorporated as part of the investigative work.

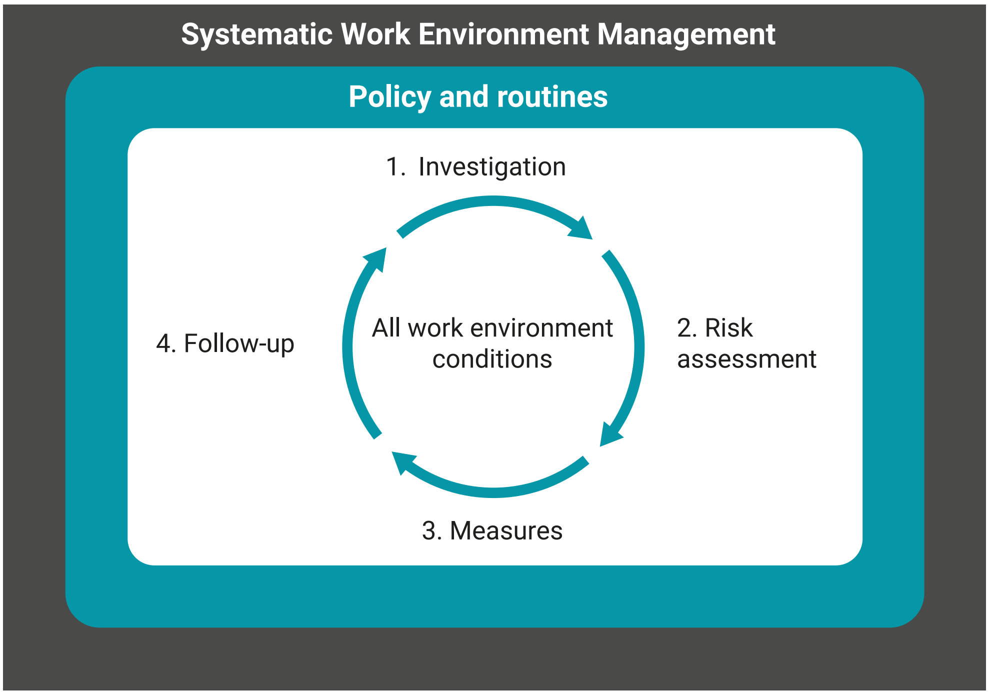


Figure 16. The Systematic Work Environment Management must be a natural part of the operations, and thus part of the organisation's routines and improvement efforts.

Important routines to have in place

There are a couple of routines which are particularly important to have in place in order to promote good visual working environment, and to be able to detect visual ergonomic risks early on and remedy them. The routines comprise:

- routines for orienting new employees
- routines for eye examinations

What: Routine for orienting new employees

Why: In addition to having to be introduced to the relevant job tasks, how the Systematic Work Environment Management operates and any risks associated with the job, a new employee should also be oriented regarding their physical work environment. Examples of this include proper working techniques and how the equipment present can be adjusted and thus tailored to the employee. In this way, the visual ergonomic aspects can be noted early on. One way of doing this is to offer the employee an ergonomic review of the workplace, at which time the visual ergonomic aspects are also examined and discussed. That often takes a while for the effects of deficiencies in visual working environment to make themselves felt. The symptoms may come on insidiously and be of a nature such that they may not be directly linked to, for instance, eye strain. It is consequently important to create the best possible conditions for preventing poor health.

What the routine should include:
How the employee is oriented in their workplace and the equipment that is to be used. This is advantageously done together with, for example, an ergonomist who, in addition to helping adapt the equipment, can provide information about key visual ergonomic aspects.

The employee needs to know about the visual ergonomic aspects of their work that are presented below:

- How the equipment being worked with can and should be adjusted so that it fits the work to be performed. Examples include chairs, desks, work objects, display screens, distances and gaze angles.
- The importance of seeing what one is working on without strain. If an employee finds that they need to strain their eyes or muscles, they can try changing the distance to the work object, or enlarging the text on the screen.
- The importance of breaks and regularly lifting one's gaze from the visually demanding tasks toward a point at least six metres away during prolonged visually demanding work so as to get so-called 'eye rest'. This should be done for at least 20 seconds every 20 minutes on at least 20 feet (6 m) distance (the 20-20-20 rule).

What: Routine for eye examinations

Why: Work glasses for visually demanding work, such as computer work, are important in being able to perform efficiently and sustainably during the workday. Good correction for close-up work improves performance capacity and leads to better working postures and fewer visual symptoms and headaches. 'AFS 2023:11', which concerns work equipment and PPE, sets out the requirement that employees who work more than one hour a day at a display screen shall be offered eye examinations regularly. To ensure that visual alterations are discovered in time and prevent associated problems, employers should have a routine for how and when eye examinations are to be performed. Eye examinations and work glasses are part of the job and must be available to the employee free of cost.

What the routine should include:

- When and how regular eye examinations are to be performed. The length of a suitable interval between eye examinations depends upon the nature of the work and the age of the employee, but 1–3 years can serve as a reference.
- In addition to being performed at set intervals, eye examinations must also be performed whenever the need arises i.e. at the onset of visual symptoms.
- Who performs the eye examination. The examination must be performed by a suitably qualified individual according to 'AFS 2023:11'. This means that the eye examination should be performed by a licenced optometrist with special visual ergonomics competence. The Swedish Optometric Association's website identifies opticians who are members of the association, and what competence they possess. Visual ergonomics competence is important, as the optometrist will then be able to factor the problems present in the visual environment into the eye examination, which is advantageous.
- A requisition specifying the information which the optometrist needs to perform a satisfactory assessment of the visual environment in the workplace. It is the optometrist who determines what type of glasses or the strengths that will suit for the job task the employee has. It is consequently important that the requisition is filled out correctly, so that the work tools (glasses) become optimal. Adequate work glasses must be tailored to the individual, and to the job to be performed, and the eye examination must be free of cost to the employee. An example of how such a requisition should be configured is found in Appendix 12.

Investigate, Risk Assessment, Remedial Measures and Follow-up

A description of how visual ergonomic aspects can be integrated into the Systematic Work Environment Management is provided in the coming section. The introductory step, **step one, investigate**, offers examples of some methods for investigating the visual working environment at the work environment at both the organisational and individual level. Part of this methodology is well suited to being applied by the employer and employees themselves, or with the support of experts in the field, while other parts are carried out by Occupational Health Services or other actors with expert competence. **Steps two and three, risk-assessment and propose remedial measures**, require more expert knowledge in the field, with the result that the ways of working and methods in those steps target mainly experts in the field. The emphasis in step four, follow-up, is on the employer, although expertise can provide key support here as well.

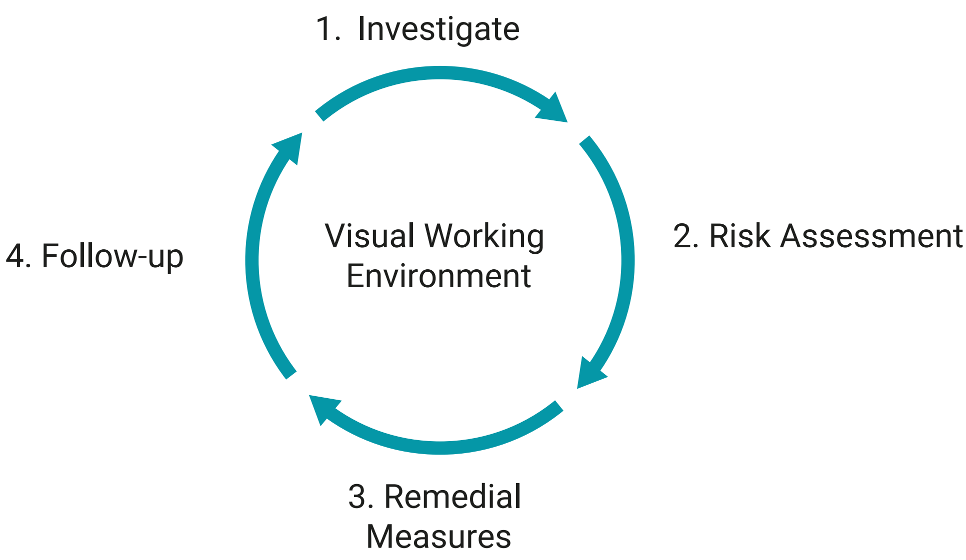


Figure 17. The process for Systematic Work Environment Management.

Step 1. Investigate

Investigating the work environment constitutes the first step in the work of improving it. Lighting and other visual working environment can be investigated in many different ways, such as through dialogue between supervisor and employees. Regularly and systematically examining the work environment with the help of checklists and methods increases the odds of including the most important factors and ensuring that no area is missed.

Examples of investigative work which can be done by the employer and employees, or by Occupational Health Services or an actor with similar expertise, are provided in Figure 18 on the next page, and described in detail on pages 66-69.

	Supervisor, safety representative, employee	Occupational Health Services or other expert
Group/ department level	• Employee questionnaires • Safety tours	• Support for safety tours • Health mapping/Health investigation at organisation/group level
Individual level	• Employee interviews • Personal checking of light/ lighting	• Health mapping/Health investigation at individual level

Figure 18. Overview and examples of methods and tools for the task of investigating the visual working environment at the group/department and individual level.

Employee questionnaires

Studies have shown that the most common indications of the consequences of visual ergonomic deficiencies are the feeling of having difficulty seeing what one is working with, headache, migraine, and various types of visual symptoms (9). Questions intended to detect these can be included in employee questionnaires. In this way, the work environment coordinator will be made aware that something needs to be investigated and risk-assessed in greater depth.

Suggested questions to include in employee questionnaires:

QUESTION: Do you find that the lighting is good enough for you to be able to do your work?

RESPONSE OPTIONS: *Yes/No.*

QUESTION: Does it happen that you have headaches or migraines that you associate with your work and, if so, how often?

RESPONSE OPTIONS: *Always/Often/Sometimes/Rarely/Never*

QUESTION: Do you ever experience visual symptoms such as dry, strained or tired eyes, or sensitivity to light?

RESPONSE OPTIONS: *Always/Often/Sometimes/Rarely/Never*

QUESTION: Do you ever experience musculoskeletal symptom in upper back, shoulders or neck?

RESPONSE OPTIONS: *Always/Often/Sometimes/Rarely/Never*

Safety tours/work environment tours

One common way of inspecting the physical work environment is to conduct a safety tour/work environment tour. This is done jointly by the employer and the safety representative/work environment representative, and Occupational Health Services or other expertise may also be brought in, depending on what is to be investigated. Additionally, employees are often the most observant concerning deficiencies in their own work situation.

Lighting is included in numerous checklists, both general ones for offices and industrial environments, and those that focus on light and lighting in particular. See the matrix of checklists and methods in Appendix 13 to select a suitable checklist. Checklists can be downloaded from the Prevent website.

Employee interview

The employee interview, which should address issues concerning the mental, physical and social work environment, shall also include a brief evaluation of how the employee perceives their visual environment. This is especially important given that vision changes over the years, and in that different types of problems may arise. The adjacent blue box offers examples of questions which can help the supervisor and employee to be aware early on of any deficiencies in the visual ergonomic design, or of any uncorrected impairment of the employee's vision. If there are suspicions that such is the case, the situation should be studied further by Occupational Health Services or an actor with similar competence.

Independent checking of light and lighting

Employees can independently investigate their visual environment in terms of vision and lighting in their workplace relatively easily, and thereby discover whether there are any types of problems that need to be addressed. Certain conditions may be difficult to detect, but a few simple methods can be used to determine whether the illuminance is sufficient, and whether the light is shining in correctly. It is not unusual to be exposed to glare, which can give rise to significant health problems, without having thought about it.

The next page provides a simple checklist which can be used by the employee to check their visual environment by themselves. The checklist can be used in such a way that the employee follows the instructions in each area and, if they detect a problem, then the visual and lighting conditions should be investigated and risk-assessed in greater detail by Occupational Health Services or another specialist.

Suggested questions to discuss in the employee interview

- How do you perceive your workplace and the equipment you use on the job; is it tailored to the job tasks you perform, and do you have all the equipment you need?
- Do you ever feel bodily symptoms; do you have pains in your neck, upper arms or other muscles and, if so, how often?
- Do you ever have any kind of visual symptoms, such as dry or strained eyes and, if so, how often?
- Do you ever have headaches which you suspect are due to your work and, if so, how often?
- Do you have work glasses, and how do you think they are working?
- When did you have your last eye examination?

Glare is often caused by light sources or luminaires that are bright in relation to their surroundings. It can sometimes be hard to detect being subjected to glare. Glare often causes headache and visual symptoms, which can be avoided by remedying whatever is causing the glare.

Checklist for independent checking of light and lighting

Illuminance
The illuminance can be screened/adjusted using mobile applications (apps). For independent checks the app 'Ljus' published by the Swedish Work Environment Authority can be recommended.

How to check the illuminance:
Follow the instructions in the app and you will get an approximate illuminance value. Bear in mind that there is a certain margin of error in the app; the scope of that margin is specified in the technical description. The error in the Work Environment Authority app is often less than 10%. If the screen displays the value 'insufficient illuminance', then the Occupational Health Services or another expert should be engaged to make supplementary measurements and investigate.

Light and the lighting direction
Determine how well your workplace meets the lighting recommendations below. If the workplace deviates from these recommendations, there are reasons to study the conditions more closely and take the necessary steps to ensure that the recommendations are met.

- It is recommended that daylight come from the side when doing work, and the work object/display screen must not be positioned directly in front of a window, or with a window directly behind. Make sure that daylight screens are present so that daylight can be screened off if disturbing.
- It is recommended that the lighting for ergonomically demanding visual work can be suspended from the ceiling. Such suspended luminaires shall be positioned along the edge of the desk closest to the worker, and be of the type that emits both indirect light that is directed upwards and reflected in the ceiling and direct light downwards over the workspace. Each light needs to be independently adjustable with a dimmer function. The indirect lighting means that the light will be distributed more uniformly in the room and in a way that reduces severe contrasts.
- If desk lighting is present, it must be well shielded or positioned below eye level to prevent glare. It should also be positioned to the side of the work object or display screen and not aimed incorrectly, e.g. at the screen, as the lighting will then pose a risk of degrading the contrasts on the screen.
- Display screens and other lighted aids should be adjustable for brightness and contrast, so that you can tailor them to your individual visual needs.

How to check the light's direction from a light source:
Lay a shiny surface/mirror on the work surface in front of you. If you see straight into any light source in your surroundings when you look down, then the light source is placed incorrectly and you have reflections that make it more difficult to see and could cause problems. Contact an expert, e.g. the Occupational Health Services, for a more detailed investigation/risk assessment and suggested remedial measures.

Glare from lighting/light source
The so-called hat-test is a simple way to check whether any lighting is too strong in relation to its surroundings (uneven light distribution occurs), which will cause you to experience glare.

How to check for glare:
Hold up both hands, a newspaper or the like above your eyes like a visor/hat brim. If this feels significantly better, then the brightness differences in your field of view are too great, and you are experiencing glare. Usually, it is a luminaire that is too bright and glaring, or a window/reflection from glass surfaces that are causing the disturbance. Contact an expert, e.g. the Occupational Health Services, for a more detailed investigation/risk assessment and suggested remedial measures.

Health checks/health mappings

Health checks/health mappings (various terms are used) can be an important means of identifying health problems which may be connected to visual ergonomic defects at the work environment. Research has identified a number of problems that are commonly linked to visual ergonomic defects, and of which one should be particularly aware (see fact box).

The health problems identified as commonly occurring here may also be due to other causes. However, it is necessary that the person who conducts/is involved in health mapping/a health check knows that the cause could be found in the visual working environment, and consider investigating and risk-assessing them further. Such knowledge must be possessed by all employees at Occupational Health Services or actors with similar competence who conduct health mapping/health checks or otherwise come into contact with people seeking help for various types of health problems.

The lower blue box to the right offers suggestions for some concrete questions that address visual working environment and can advantageously be incorporated into forms used in health mapping/health checks. The questions come from the 'VERAM risk-assessment method', which was developed at the Faculty of Engineering, Lund University (125, 126).

Vision screening

Performing a simple form of vision screening in conjunction with health mapping/health checks can also be an important means of getting some idea of the conditions under which the work is being done, and whether any visual impairments are present that need to be examined more closely.

An example of a vision screening form is found in the list of checklists and methods, and in its entirety in Appendix 14.

Examples of health problems due to visual ergonomic defects*:

- Visual symptoms such as blurred vision, red eyes, dry eyes, tired eyes
- Headache
- Musculoskeletal symptoms in neck and shoulders

* Read more about symptoms and their causes in *'Visual ergonomics – a brief introduction to the facts'*

Suggested questions to supplement questionnaires for health mappings/ health checks

1. How do you find the light and lighting conditions in your workplace?
2. Do you find that you see well enough to be able to do your job tasks without problems?
3. Do you have headaches or neck/ shoulder symptoms?
4. If 'yes' to the previous question, to what extent do those symptoms affect you in your work?

An expert should be brought in for further assessment if the lighting is found to be deficient, or if any sorts of problems are found.

Step 2. Risk assessment

Appendix 13 lists suitable methods and checklists for supporting risk assessments in which visual ergonomic aspects are incorporated in various ways. The method used is appropriately determined using this matrix, based on the visual ergonomic aspects that are deemed important to include in the risk assessment.

Some of the checklists and methods recommended are relatively simple in nature, and are suitable for use by supervisors, safety representatives and employees involved in Systematic Work Environment Management. However, most are intended for those with specialised knowledge in visual ergonomics.

The type of risk assessment and method to be used in each individual case depend in part upon the underlying reasons for the risk assessment and the type of operations in question. A risk assessment may be performed for many reasons, and can be occasioned by different parties, e.g.:

- A risk assessment is conducted for preventive purposes as part of the Systematic Work Environment Management.
- Investigative work has identified defects that need to be studied in greater depth.
- One or more employees are experiencing some type of musculoskeletal symptoms or other health problems that could conceivably be due to the ergonomic design of the workplace.
- An ergonomic study to prevent musculoskeletal symptoms has identified risks associated with visual ergonomics that need to be investigated further.

The sections below concern mainly the performance of visual ergonomic risk assessments in which measurements and assessments of the lighting conditions are included.

Remember to…

…be aware of symptoms and health problems that could be due to defects in the ergonomic design of the workplace. An initial visit to the Occupational Health Services may be to the occupational health nurse, physicians, educationist, psychologist or ergonomist, depending on the problem. Broad knowledge of symptoms that may stem from visual ergonomic defects and evolved collaboration between various Occupational Health Services resources are important in taking the right types of steps to address the problems causing the symptoms.

Visual ergonomic risk assessment

A visual ergonomic risk assessment is intended in particular to identify and assess risks associated with the visual working environment. A vision ergonomic risk assessment can be performed for a single employee or for an entire department/organisation, depending upon the underlying causes and needs. Risk assessments need to be planned and conducted in different ways, depending upon the workplace in question, the job tasks being performed, the current situation, any problems or symptoms being experienced, the scope of the workplace, and a host of other factors which may serve as the basis of or impact the risk assessment. Figure 19 describes a general process for conducting a visual ergonomic risk assessment. This is followed by a description of some of the methods also found in the matrix (see Appendix 13).

Three case descriptions (see pages 84-95) are provided to further elucidate how a risk assessment can be conducted and what considerations one may face. They are to be viewed as examples that offer both guidance for planning and execution and indications of how different situations and circumstances require situational adaptation of the risk assessment.

General process for planning and conducting a risk assessment

<table>
<tr><th></th><th></th><th>Individual</th><th>Group/department</th></tr>
<tr><td rowspan="4">Preparations</td><td>1</td><td>Engage in dialogue with the employee’s immediate superior (the principal) to determine the content and scope of the task. Make it clear that the safety representative is welcome to take part in the risk assessment initially, if the individual so desires.

NOTE! Obtain supervisor’s consent before any photography/filming</td><td>Engage in dialogue with the principal to determine the task’s purpose, scope, issue, and how the task is to be reported, and to whom. Make it clear that the safety representative is welcome to take part in the risk assessment.

NOTE! Obtain supervisor’s consent before any photography/filming</td></tr>
<tr><td>2</td><td colspan="2">Formulate the purpose and objectives of the task, how and when it will be carried out, and the responsibilities of each party. Also discuss how the task will be followed up. Coordinate the written task description with the principal so that you are in agreement as to the scope and execution of the task.</td></tr>
<tr><td>3</td><td colspan="2">Select a suitable risk-assessment instrument based on the issues addressed in the task; see Appendix 13 for different methods and checklists. Choose suitable equipment needed for the risk assessment, e.g. measuring tape, light meter, or camera.

Appendix 10 describes how to measure and calculate illuminance and luminance. Recommended values for some workplaces are provided in the chapter entitled ‘The workplace’s visual environment’, and in Appendix 2. Appendix 3 also presents an example of a measurement protocol in which measurement data and observed light conditions can be documented. It also serves as excellent support in planning measurements.</td></tr>
<tr><td>4</td><td colspan="2">If the risk assessment includes a subjective portion (e.g. a questionnaire), make sure that the questionnaire is made available to the employee(s) before the physical risk assessment date.</td></tr>
<tr><td rowspan="3">Execution</td><td>5</td><td colspan="2">Carry out risk assessment and measurements as per the selected method. If you find that you are not capturing all the risks, choose a supplemental checklist/method. NOTE! Don’t forget the musculoskeletal/ergonomic aspects.</td></tr>
<tr><td>6</td><td colspan="2">Process the material you have gathered. The section entitled Rating risks later in this chapter offers guidance on how to rate different types of risks. Ratings provides good support for prioritising which risks should be addressed.

Suggest remedial measures for the identified risks.

It is a good idea to consult with an experienced colleague regarding results and remedial measures.</td></tr>
<tr><td>7</td><td colspan="2">Summarise the risk assessment in a written report.</td></tr>
<tr><td rowspan="2">Reporting & follow-up</td><td>8</td><td>Present/feedback results of the risks assessment to the individual and their supervisor.</td><td>Presentation/feedback to ordering supervisor and department/group as agreed in task description.</td></tr>
<tr><td>9</td><td colspan="2">In connection with the reporting, schedule time to follow up with the principal on what has been done following the risk assessment, and on the measures implemented. The follow-up time may vary depending upon the scope of such measures. Agree with the principal on a suitable date for the follow-up.</td></tr>
</table>

Figure 19. Process for planning and performing a visual ergonomic risk assessment.

Description of risk-assessment methods for experts:

VERAM risk-assessment method
The 'Visual Ergonomic Risk Analysis Method (VERAM)' is a validated and reliable method for comprehensive risk assessment and is designed mainly to be used at the individual level (125, 126). The method consists of two parts, i.e. a subjective part with questions which the employee answers, and an objective part in which the assessor measures and assesses visual ergonomic risk factors such as illuminance, glare, daylight, the lighting design, the design of the visual environment, the presence of flicker, and working postures. There is also a feedback section for the employee, which offers detailed recommendations and suggested remedial measures. Special training in visual ergonomic risk assessment is needed to use 'VERAM'. A risk assessment usually takes 1–1.5 hours per workplace to complete and is suitable for investigating relatively difficult or hard-to-assess cases in depth. A short version is, however, described below.

VERAMlight risk-assessment method
'VERAMlight' is a screening version of 'VERAM' and, like 'VERAM', is suitable for assessing risk at the individual level, although it may also be suitable for use at the group/department level. The method includes a subjective questionnaire and selected objective light measurements, plus risk assessment at a more general level. Here again there is a feedback section for the employee, plus general recommendations and suggested remedial measures. Like 'VERAM', using 'VERAMlight' requires training in visual ergonomic risk assessment. 'VERAMlight' takes roughly 15 minutes per workplace to perform.

Both 'VERAM' and 'VERAMlight' were developed by the 'Faculty of Engineering' at Lund University. For access to the method and special training in visual ergonomic risk assessment, seek out training at the 'Swedish School of Work Environment and Leadership' at the Lund University Faculty of Engineering, or contact Hillevi Hemphälä.

Detailed lighting/visual ergonomics checklist for specialists
The 'Detailed checklist for lighting/visual ergonomics' for specialists is suitable for use in risk-assessing an enterprise or facility in which multiple employees are working. The checklist includes an objective assessment and lighting measurements, but has no subjective section. It can be used in a general risk assessment of the enterprise as whole, as well as for individual employees. For detailed instructions on how a risk assessment based on the checklist should be carried out, see Appendix 17.

Visual ergonomics questionnaire with visual symptoms index
An initial assessment can be made by calculating a visual symptoms index for a group/department based on a simple subjective evaluation so as to obtain an initial idea of the incidences and experiences of typical problems that may have their roots in visual ergonomic deficiencies. The index will then guide the way in terms of the need for a more detailed risk assessment.

The visual symptoms index captures eight different types of eye problems, including gritty sensations, burning sensations, red eyes and sensitivity to light, and is calculated for the group based on employee perceptions of incidence and symptoms. The visual symptoms index was developed based on a questionnaire formulated by Knave et al. (127). The index has not been published in English, but a translation is presented here for knowledge and as an alternative method. The questionnaire as a whole also serves as the basis for the questionnaire included in the 'VERAM' and 'VERAMlight' methods. The calculation of a visual symptoms index is not a scientifically validated method, but rather one that has been practically applied for many years, thus becoming practice. The questionnaire and a description of its use are presented in Appendix 15.

Checklist for visual ergonomics workplace visits
The Checklist for visual ergonomics workplace visits is a shorter and simplified tool for investigating workplace design, visual symptoms and light measurements, and is suitable for a visual ergonomics workplace visit. The checklist was created by the Swedish Occupational Optometrists Association (SFF), and presented at the Nordic Ergonomics Society conference in 2012 (128). The checklist can be used for both individuals and groups. It can be found in Appendix 16.

Measuring lighting and luminance ratios
Measuring lighting and luminance ratios is a key element in the risk assessment. Measurements are included as part of most of the risk-assessment methods and checklists cited in these guidelines. The chapter entitled 'The workplace's visual environment' describes how illuminance and luminance are measured and what to bear in mind when making such measurements, and offers light/lighting recommendations. Appendix 3 also includes a separate protocol for measuring illuminance and luminance.

Rating risks

Rating risks based on the severity of injuries and symptoms and the likelihood that injuries or symptoms will occur constitutes an important part of the risk-assessment process. Rating risks makes it possible to prioritise them and offer guidance as to the remedial measures that should be implemented immediately, and in both the short term and the longer term. The risk assessment must be as objective as possible, which is why methods and rules are important as support in the assessment process.

Many of the risk-assessment methods recommended for visual working environment focus primarily on identifying risks, and include no instructions for rating risk levels. There are consequently two models to support the rating of risk levels on pages 75-76.

Risk-level rating with consequences for injuries/symptoms
A risk-level rating process has been formulated to assess musculoskeletal injuries which can, in practice, also be used to rate the levels of visual ergonomic risk in terms of the consequent injuries to which the risks can give rise. It derives

from the Swedish regulations regarding musculoskeletal injuries, 'AFS 2023:10', which concerns workplace risks, and has been developed in these guidelines in such a way that the rating process takes not only musculoskeletal symptoms into account, but also symptoms such as visual symptoms and headache. This has been done based on the symptoms which studies have shown commonly result from deficiencies in visual working environment.

The risks are assessed based on a three-grade scale, where three (red) means that all or most of the risk-assessed employees will sustain injuries or exhibit symptoms in the short or long term. The red risks shall consequently be addressed first. The person performing the risk assessment needs to provide clear feedback to the employer as to how great the risks of, e.g. neck problems, visual symptoms or headaches are, based on the visual ergonomic risk assessment. The graded assessment offers the employer excellent support in deciding the order in which remedial measures should be implemented.

Table 10. Rating of risk levels with consequent injuries/symptoms.

Risk level	Incidence of risk	Severity	Consequences
1	Occurs rarely	Low risk, minor symptoms may occur	Acceptable. Low probability that individuals may develop musculoskeletal problems, visual symptoms or headache. Usually no remedial measures are needed, although certain individuals may require action.
2	Occurs sometimes	Some risk, moderate symptoms may occur	Assess in greater depth, i.e. in-depth risk assessment to clarify what remedial measures are needed. Many people could develop musculoskeletal symptoms, visual symptoms or headache. Implement remedial measures as soon as possible.
3	Occurs often or daily	High risk, moderate-to-pronounced symptoms may occur	The majority could be affected by musculoskeletal symptoms, visual symptoms or headaches in the short or long term. Implement remedial measures immediately.

Rating based on identified visual environment

The identified risks can also be rated based on the visual environment identified in the risk assessment, see Table 11. This rating process derives from the 'VERAM risk-assessment method handbook' (101).

Table 11. Risk-rating levels based on identified visual environment, modified from 'VERAM' (101).

	Risk level		
Conditions in the risk assessment	**Green**	**Yellow**	**Red**
Daylight	Good access to daylight	Acceptable access to daylight	Poor access to daylight
	No glare from daylight	Low risk of glaring daylight	Glare from daylight
	Good direction of daylight	Acceptable direction of daylight	Disturbing direction of daylight
	Means of screening daylight	Limited means of screening daylight	No means of screening daylight
	Employee not disturbed by the daylight	Employee sometimes disturbed by daylight	Employee often disturbed by daylight
	Good outdoor view/access to windows	Acceptable outdoor view/access to windows	No outdoor view or access to windows
Lighting – general	Both direct and indirect lighting	Most direct lighting, little indirect lighting	Only direct lighting, e.g. recessed LED panels against a dark ceiling
	Light direction is appropriate for the job task	Light direction causes minor but disturbing shadows or reflections on the work surface	Light's direction causes major disturbing shadows or reflections on the work surface
	Good colour rendering	Low colour rendering	Poor colour rendering
	Good means of changing/dimming the lighting	Limited means of changing/dimming the lighting	No means of changing/dimming the lighting
	Employee considers the light to be good for performing the job tasks	Employee considers the light to be borderline sufficient to perform their job tasks	Employee considers the light to be insufficient to see their job tasks
Lighting intensity	Measured lighting intensity is well adjusted to recommended values	Measured lighting intensity is somewhat low compared to the recommended values	Measured lighting intensities are insufficient compared to recommended values
	Uniformity value is sufficiently above the recommended value	Uniformity value is somewhat lower than the recommended value	Uniformity value is too low compared to recommended values
	Employee considers the lighting intensity to be good	Employee finds the lighting intensity to be borderline adequate	Employee considers the lighting intensity to be insufficient/poor
Glare	The luminance ratio within the field of view is good	The luminance ratio within the field of view is borderline acceptable	Luminance ratio within the field of view is too high
	Employee experiencing no glare from luminaires	Employee sometimes experiences glare from luminaires	Employee often experiences glare from luminaires
	No objective glare from luminaires	Minor objective glare from luminaires	Objective glare from luminaires
	Luminance ratio for visual field: <1:5	Luminance ratio for visual field: More than 1:5 and less than 1:20	Luminance ratio for visual field: >1:20
Flicker	No visual flicker	No pronounced visual flicker	Pronounced visual flicker occurs
	No non-visual flicker present: No striped pattern in camera image	Non-visual flicker may occur: Weak striped pattern in camera, or weak stroboscopic effects/phantom arrays	Non-visual flicker occurs Strong striped pattern in camera, or stroboscopic effects/phantom arrays

Examples of common risk factors

The checklists and methods recommended for risk-assessment of visual working environment offer good guidance in identifying risks in an existing work environment. Practical experience has identified some situations/problems which have proven to be common in numerous different workplaces and industries, and can serve as support in the work of identifying areas of risk. The box below provides examples of several such commons situations/conditions.

Situation/problem

- One or more employees choose to turn off their ceiling luminaires because 'they do better like that'. There can be a number of reasons for such a perception, e.g. non-visual flicker, overly intense lighting, glare, or incorrectly positioned lighting.
- Luminaires are obviously misplaced in the room, as they were not shifted in connection with repositioning of the furniture.
- Employees do not know about or avail themselves of the possibility of changing the placements of task lighting that is not fixed or, for example, adjusting (dimming) the lighting if possible.
- Employees do not think to or know how to adjust the brightness and contrast on their display screens.
- The luminaires present in the workplace are not suitable for the work being done. Read more about choosing luminaires on pages 33-34.
- LED panels recessed in the ceiling are a common general solution in open-plan office landscapes and other larger spaces. They are often found to be too intense or glaring against a dark ceiling. Read more about choosing luminaires on pages 33-34.
- Display screen(s) are incorrectly positioned in relation to incoming daylight. The daylight should come in from the side, not from the front or rear, as that can cause reflections and contrast glare.
- Display screens are incorrectly placed, e.g. too close, too far away, or at the wrong height. This gives rise to uncomfortable postures. Read more about the distancing and placement of display screens on pages 40-41.
- The display screens are surrounded by a high-gloss, often black frame that causes reflections and contrast glare. See advice for display screen procurements on page 41.
- The workplace contains very light or dark desks/worktables that produce contrast effects due to excessive differences in luminance distribution. The reflectance from table surfaces and other prominent objects should fall in the range of 0.2–0.7. This means that the surfaces should be pale wood-coloured or weakly monochrome, e.g. a pale grey colour, and not black or white. Read more about selecting equipment on pages 39-40.
- Employees lack or have improperly designed work glasses, if needed. Read more about work glasses and eye exams on page 77.
- Two screens may be present at the same workstation that are of different types, ages or sizes. This can give rise to differences in brightness, sharpness or contrast. If multiple screens are used, they should be of the same manufacturer, size and conformation.

Step 3 Remedial measures

Once the risk assessment is complete, the next step is to propose remedial measures to eliminate or reduce the identified risks. The measures should be prioritised based on the risk level rating.

Occupational Health Services or another actor with similar competence can, based on their specialist competence, suggest appropriate measures to address the prioritised risks, and offer support and assistance in implementing those measures. The remedial measures are appropriately presented in a report that also includes the results of the risk assessment. The report is always submitted FYI to the employer and to the safety representative, if the workplace has one. The results can also advantageously be presented verbally, if so, agreed with the employer. It is crucial that all affected parties receive the results and recommended remedial measures, regardless of whether the risk assessment was conducted at the organisational or individual level.

Based on the proposed measures, the employer then has the important task of preparing an action plan and scheduling the implementation of the adopted measures, and of appointing a coordinator to implement them.

Examples of visual ergonomic risk factors and types of proposed remedial measures

It is difficult to offer precise recommendations for measures to address deficiencies in visual working environment, as the problems can be attributable to complex correlations, needs and circumstances in different workplaces. This means that problems can be solved in many different ways, and it is crucial that the solutions be tailored to the workplace and individual in question.

However, based on studies using 'VERAM' (100, 125, 126, 129, 130), a number of common risk factors can be identified, as can the types of measures that are appropriate for them. The matrix in Table 12 consequently offers general guidance in choosing various measures on which to focus.

Figure 20 on also offers guidance regarding preventive measures for older employees. This can also be viewed as good guidance that contributes to good visual working environment for both young and old employees.

Who does what in the remedial work?

Occupational Health Services or other experts

- Rate the risks
- Propose remedial measures
- Propose prioritisation of those measures
- Support the work of implementing measures and following up on their impact.

Employer

- Prepare action plan with adopted measures and schedule their implementation.
- Appoint coordinator(s) to implement measure(s).
- Implement prioritised and adopted measures.
- Follow up action plan and impact of the implemented measures within the framework of the Systematic Work Environment Management.
- Get help from specialists as needed to assess whether results are satisfactory, or whether deficiencies/risks/problems remain.

Table 12. Common risks/deficiencies and types of measures to focus on.

Type of measure	Risk factor							
	Incorrect illuminance	Mispositioned luminaires	Wrong luminaire type	Lack of daylight	Glaring daylight	Work distance/visibility	Subjective visual symptoms	Ageing eyes
Adjust illuminance	•	•		•			•	•
Even out luminance ratio	•	•	•	•	•			•
Reduce reflections	•	•			•		•	•
Reposition luminaires	•	•					•	
Supplement luminaires	•	•	•	•				•
New luminaires	•		•	•				
Screen off glaring daylight or move work object so that daylight comes in from the side					•		•	•
Meet daylight requirement*				•			•	
Adjust/improve working distance/posture						•	•	•
Improve visibility of work task						•	•	•
New/supplementation of work equipment						•	•	•
Rest gaze						•	•	•
Referral for glasses						•	•	•

** Most daylight requirement suggests a daylight factor of about 1–2% i.e. indoor light must consist of 1-2% daylight. But other alternative measures are recently suggested e.g. useful daylight illuminance, UDI (131).*

Tips on special solutions/measures for some specific occupations

Different occupations face different types of challenges, given the nature of the job tasks. Several occupations are described below for which special solutions exist that are helpful to know about.

Dentists: Dentists are often subjected to stressful postures that affects their neck, shoulders and arms, as they often work while bending forward. So-called 'prism glasses' are recommended to reduce this forward bending of the neck, and the resulting stress. This reduces the need to bend the neck forward. In designing the dentist's work environment, it is also crucial that the workplace be optimised for good ergonomic conditions.

Electricians: Electricians often do their work in and/or above shoulder level, resulting in backward bending of the neck. Glasses with the reading window ground in at the top can reduce such bending of the neck. So-called 'clip-on' glasses can also be worn over the glasses for close-up work performed while looking upwards.

Pilots: Pilots have problems similar to those of electricians in terms of the placements of instruments in the ceiling of the cockpit. Progressive glasses with the reading window ground in at the top can contribute to better working postures. This applies to individuals whose eyes are undergoing incipient age-related changes.

Postal workers: Sorting work involves frequent bending of the head when the address is read with the hand at middle height, with the letter then being placed in the sorting box, which is between knee and shoulder height. Such forward bending can be reduced with the proper technique, i.e. holding the elbow close to the body and holding the letter just below shoulder height, while reading the addresses. An aid for this is available in the form of a stabilizing vest in which the stack of letters can be placed, rather than holding them in the hand. This reduces the tension on the neck/shoulders. It is crucial to have glasses that are adapted based on the working distance, particularly for individuals undergoing incipient age-related changes (begins roughly at 40–45 years of age). There is also a solution involving double-faced frames (a foldable part on the outside of normal glasses frames), where the distance strength is present in the rear front and a pair of flip-up progressive close-up lenses is present in the front foldable part. This makes it possible to access the right strength for the viewed distance.

Control room work: This work often involves keeping different tabs open on multiple display screens at different heights and distances. It is crucial to position the screens so that the job tasks do not entail overly long viewing distances, which can degrade legibility, and to avoid excessive and frequent switching between different viewing distances. The screens must also be placed so that the employee need not direct their gaze upward for extended periods of time. Avoid screen placements that result in viewing angles deviating less than 15 degrees downwards from the horizontal plane (132-134). This leads to problems and challenges in terms of both screen visibility and uncomfortable working postures, due in part to different neck angles. When progressive glasses are used, this leads to major problems with regard to the neck angle.

Crane operators: When there is a need to see down through the glass floor in the cab (which can sometimes be more than 25 metres up in the air) and down to the ground, the lenses in the frames of progressive glasses can be brought up and down, so that the operator uses the distance strength when looking downward and the reading strength to look at the screen while looking straight ahead.

Laboratory personnel: Reading test tubes: the background surface must be of made of a non-reflecting material, e.g. a neutral surface such as a wall rather than a window, mirror or glaring light. When working at a microscope, make sure that it is possible to assume a relaxed working posture. If a microscope is being used together with a display screen, the same recommendations concerning work glasses apply as for computer work.

Vehicle painting: Vehicle painters perform visually demanding precision work involving considerable hand/arm strength. The placement of the lighting is of major importance, and the lighting needs to be adjusted as the work position changes, so that the painter can see well. Straight light stripes that are reflected in the painted surface or spotlights that can be rotated vertically and horizontally and are mounted on wheels are recommended. They enable the painter to move them about so that optimum visual environment can be achieved.

Occupations with heavy contrast-vision requirements, such as inspection work: Different kinds of filter lenses or tinted lenses in the glasses can advantageously be used to enhance vision. Many different tints and filters are available; the optometrist can choose together with the employee, as it is crucial that personal preferences are taken into account. Magnifying aids such as a magnifying lamp mounted on an adjustable arm secured to the work table can serve as excellent aids to inspection work. It is important that the aid be positioned so that a restful working posture is achieved, and that there is adequate lighting within the inner and outer work areas.

Forklift drivers: The job of a forklift driver involves long-term sitting still with static stress on the neck, shoulders and head. It often also involves uncomfortable working postures, with twisting and backward bending of the neck to be able to see well. There is often a display screen mounted in the forklift, which the driver needs to see/work with. Glare can occur on the screen, depending on the forklift's position on the premises or outdoors. Their job tasks require the forklift driver's gaze to switch between many different distances, and there is also a major risk of glare.

Some modern forklifts are equipped with laser aids that can point out objects and facilitate precision work. Forklift drivers shall undergo regular eye exams, and glasses shall be tailored to their needs.

Forklift drivers often drive between indoor and outdoor environments. It can take several minutes for the eyes to adjust from bright light to darkness, and enough time is usually not allotted. Forklift drivers are often faced with this so-called temporary blindness. One way to prevent this type of blindness is for the driver to wear sunglasses when departing, lighter lenses in winter, and darker ones in summer. Drivers who already have glasses can be provided with clip-on sunglasses.

Adapting light conditions for older employees

Special consideration needs to be given to the design of lighting and visual ergonomics so that older employees will be able to perform visually demanding tasks properly. The next page provides a checklist for help in adapting light conditions for older individuals. It was compiled based on the section on ageing in the chapter entitled *Visual ergonomics – a brief introduction to the facts*. The remedial measures will enable improved visual ergonomics for younger people as well.

Illuminance	Can the illuminance in the workplace be adjusted individually up to three times higher than the general recommendations? Is adjustable panel lighting or extra work lighting available to increase the illumination of the work object? Is the illumination adjusted gradually in the transitions between areas or spaces with more illumination and those with less?
Luminance	Are the luminance ratios uniform, i.e. maximum of 5:3:1 in the field of view? Is indirect light available from the ceiling? Can contrasts be enhanced so that objects, level differences and obstacles can be distinguished easily, and to facilitate depth perception?
Direction of light	Does the light come in from the side/above and directly from behind? Can light from light sources aimed at the eyes be avoided? Is the general lighting diffuse and indirect together with the direct downward light? Are the luminaires positioned correctly in relation to the work task?
Glare	Can strong luminance contrasts in the field of view be avoided, i.e. contrast glare with luminance ratios above1:5 low risk for glare or more than 1:20 high risk for glare? Can direct glare from luminaires and indirect glare in the angular range of 0–60° upwards from the horizontal plane be avoided? Are luminaires equipped with effective glare protection? Do the windows have glare protection or blinds?
Reflections	Can light reflections toward the eyes from table surfaces or shiny flat surfaces be avoided?
Shadows	Can grazing light be used to enhance contrasts from surface disuniformities? Can shadows of viewed objects be avoided, particularly shadows cast by sunlight?
Colour rendering	Is the colour rendering acceptable (R_a/CRI 80-90) for tasks that require color vision?
Daylight	Is the colour rendering according to recommended values in EN 12464-1 for the lighting on job tasks. Are daylight and an outdoor view available for wellbeing and a synchronised circadian rhythm? Is it possible to screen off disturbing daylight?
Glasses	Are glasses used that are tailored to the individual’s vision at relevant viewing distances, or for alternating viewing distances if the job task so requires, such as work glasses for computer work? Are magnifying glasses available for detail work? Are special solutions used for job tasks with special needs, such as prism glasses?
Viewed object	Is the contrast between the viewed object and the background high, i.e. at least 0.4? Is the character size higher than 16 minutes of arc (2 millimetres at 30 centimetres distance)? Can indistinct viewed objects or objects with poor edge definition be avoided?
Field of view	Are colours on walls and ceilings pale and matte (respective reflectance values of 0.5–0.8 and 0.7–0.9)? Are table tops pale, but not white (reflectance value of ca. 0.7)?

Figure 20. Remedial measures and adaptation of lighting and light conditions for older people. The list is based on references 50-58.

Step 4 Follow-up

Follow up is important in making sure that the adopted remedial measures have been implemented, and to assess whether the measures which have been implemented were appropriate, or sufficient. Perhaps some measure has given rise to a new risk? If so, the new risk needs to be assessed and remedied.

The employer is responsible for follow-up of measures implemented in accordance with the established action plan. The Occupational Health Services or another specialist who conducts a risk assessment and proposes remedial measures also performs an important function in the follow-up effort. The follow-up should include a discussion of the extent to which measures have been implemented, whether any issues have arisen in the work, and whether there is a need for further initiatives and support for the work.

Follow-up checklist

- Have all remedial measures been implemented?
- Are the measures sufficient?
- Have the measures created new risks?

Source: Swedish Work Environment Authority

Case descriptions – from risk assessment to follow-up

Three examples of visual ergonomic risk assessments based on practical experience are provided on the pages that follow. The three case descriptions target each of the guidelines' focus areas, and are intended to offer guidance regarding both the process and the importance of tailoring the risk-assessment procedure to the issues faced in the situation in question. The cases are based on risk assessments conducted in practice. The three case descriptions are:

1. Age-related visual symptoms associated with computer work (individual level)
2. Light and lighting in an open-plan office (organisational level)
3. Working at different viewing distances in dentistry (individual level)

Case 1: Age-related visual symptoms associated with computer work

Case and questions

A CEO (chief executive officer) contacts the occupational health nurse after chatting with an employee and learning that the employee is experiencing worsening visual symptoms in the daily office work. The employee often has tired eyes and feels sensitivity to light. The employee is 63 years old and holds an administrative position which involves working at a single display screen for essentially the entire workday. The occupational health nurse consults their team and it is decided that an ergonomist will take on the case. The ergonomist contacts the CEO and suggests a visual ergonomic risk assessment of the employee's workplace, whereupon the case is formalised in a written agreement.

Preparations

Following discussion with the CEO and an introductory interview with the employee, the ergonomist has gained some idea of the situation and the relevant circumstances. The employee has their own office and likes their job, but has been experiencing various types of symptoms for some time. These manifest as sensitivity to light, tired eyes, and neck and shoulder pains that are not going away, but rather getting worse over time.

The following methods and equipment are chosen:

- Risk assessment and measurements of light and lighting using the 'VERAM' risk-assessment method.
- Light meter needs to be used, and in this case a 'Hagner Screenmaster' is chosen.
- The risk assessment will be documented with photos, and so permission to take photos is needed from the employer.

The risk assessment is also based on the following regulations: '2023:11' which concerns work equipment and PPE', '2023:10' which concerns workplace risks, '2023:12' which concerns workplace design' and '2023:1' about Systematic Work Environment Management.

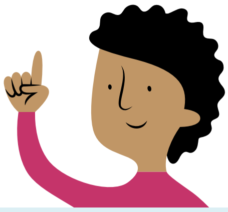
Execution and results

One week before the agreed date for the risk assessment, the employee is asked to fill out the questionnaire that constitutes the subjective portion of 'VERAM' or 'VERAMlight'. The questionnaire is accessed as a link to an electronic form, or as a PDF-file. The objective risk assessment, including measurements of light and lighting conditions, is taken up at the physical meeting. The execution of a risk assessment using 'VERAM' is described in detail in the 'VERAM handbook', and the recording of observations and data is noted in the digital module included in 'VERAM'.

The identified risks and potential consequences are then rated in terms of their risk levels with the help of guidance from 'VERAM', i.e. risk-level rating based on identified visual environment and risk-level rating with consequences in terms of injuries/problems; see Tables 11 and 10 in these guidelines.

Table 13. Description and assessment of identified risks.

	Description of risk	Risk level
1	The questionnaire indicates that the employee has neck/shoulder symptoms and visual symptoms that occur daily or often and involve significant pain.	🔴
2	The desk is positioned so that light coming in from windows behind strikes the display screen. This can cause glare and reflections from the display screen.	🔴
3	The employee's workspace is bounded by a glass wall facing the corridor. A light that strikes the centre of the field of view when the employee looks at the display screen is suspended from the ceiling. The window offers means of screening the light in the form of blinds, but light gets in between the slats and creates disturbing reflections. The desk is pale wood, and a large black mat is positioned beneath the keyboard on the desk. There is also a Mousetrapper, which is also black. The luminance ratios deviate from the recommended 5:3:1, but are below 20:5:1.	🟠
4	The workplace lighting consists of a suspended luminaire with upward/downward light. It is positioned behind the desk. The employee usually has only the downward lighting turned on. The illuminance on the inner work area proves to be insufficient (below 500 lux), as the luminaire is incorrectly positioned.	🟠
5	The employee has special progressive reading glasses for computer work, which they always use. The glasses are over three years old. During computer work it is noted that the employee bends their head back so as to be able to read through the screen portion of the glasses, which indicates that the glasses are not properly designed.	🔴



All risks are considered to fall within the yellow and red risk levels. The ergonomist finds that all the risks should be remedied, with the red ones taking priority.

With the measures implemented, the risk-level rating is found to decrease to level 1 (green).

Remedial measures and recommendations

- The desk should be repositioned so that incoming light comes in from the side in relation to the display screen.
- A curtain is hung in front of the glass wall to eliminate the glare from the ceiling lighting in the corridor.
- A curtain is set up in the window to screen off the disturbing daylight coming in between the blind slats.
- The workplace light is repositioned so that it hangs directly above the inner work area. The upward lighting must always be on, so that there is enough general lighting.
- Supplemental upward lighting is needing so that the light is distributed uniformly in the room.
- The black mat on the desk is removed to eliminate sharp contrasts with the desk. The luminance ratios then remain within the recommended value, i.e. 5:3:1.
- The progressive reading glasses are incorrectly ground for computer work. Contact with an optometrist is recommended to obtain new glasses that are suited to the work situation.
- Adjust the screen brightness and contrast to meet the employee's specific needs.
- Supplement other lighting with task lighting to increase the illuminance on the desk.
- During the visit, provide general instructions and information about appropriate working heights and the importance of variation.
- Schedule new follow-up with new light measurements once remedial measures have been implemented.

The execution, results and suggested remedial measures are documented in a report which is provided to both the employer and the safety representative. Follow-up is scheduled for four weeks later.

Follow-up

At the follow-up, the desk has been repositioned and the workplace lighting shifted and positioned correctly in relation to the work surface. The lighting has been supplemented to rectify deficiencies in the luminance ratios, and the screening measures, i.e. curtains for windows and the glass wall, are also in place. The employee has also obtained new glasses. During the follow-up, the employee is assisted in adjusting the sharpness and character size on the screen, and the importance of variation and eye rest is stressed again. The light measurements now indicate good lighting and luminance ratios. A new follow-up meeting with the employee is scheduled to follow up on the course of the problems experienced earlier.

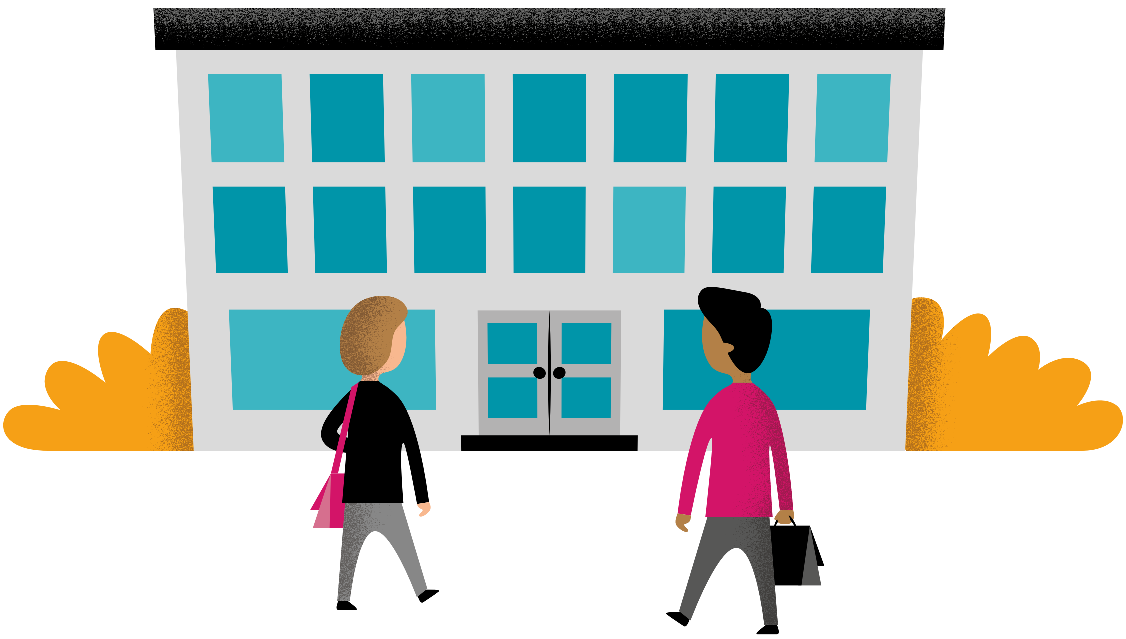
Case 2: Glaring LED lighting in an open-plan office

Case and questions

A department has 35 employees who are working in an open-plan office landscape. Their job tasks involve computer work roughly 90% of the time. They are in disagreement over how the illuminance should be set in the open-plan office, and this has escalated into a work environment problem. The situation arose when the office was remodelled two years earlier. The employees have suggested that new table luminaires be procured to solve the problem, but the safety representative and supervisor first want to investigate the underlying cause of the employees' dissatisfaction and differing perceptions of the illuminance in the space. The Occupational Health Services engaged by the company is contacted by the department manager for advice about and help in assessing the situation. An ergonomist from Occupational Health Services is assigned the case.

Preparations

The ergonomist has an introductory meeting with the manager and safety representative to gain a deeper understanding of the problem. In the preparatory stage, the ergonomist reviews the drawings of the premises, thereby gaining knowledge about the disposition of the lighting in relation to the furnishings. The ergonomist also obtains production specifications and technical data about the general lighting, and then contacts the responsible facilities planners for supplemental information.



The general lighting in the open-plan office consists of 42 recessed LED ceiling panels (3 000 K). The general lighting is controlled from a central control system with a dimmer function. The control system is mounted on one of the walls in the facility.

The following method and equipment are chosen:

- The risk assessment is based on the 'Detailed lighting/visual ergonomics checklist for specialists' (Prevent) and is planned to be carried out at ten randomly selected computer workstations spread evenly throughout the open-plan office. The *hat-test* is also used during the risk assessment, and the employees are interviewed about their computer work.
- All the employees fill out the 'Visual ergonomics with visual symptoms index questionnaire'. It is disseminated in advance as documentation prior to the risk assessment. The employees will also be asked supplemental questions about neck/shoulder symptoms associated with computer work, and about how long they have been working at their current job tasks.
- Light measurements are planned to be made at ten randomly selected workstations. In this case the 'Hagner Screenmaster' is used for the measurements.
- The Swedish Work Environment Authority's app *Ljus* is used to detect the presence of any non-visual flicker below 110 Hz. The test is then performed on an LED ceiling panel in the open-plan office. The LED lighting is also filmed to see whether stripes appear that could be indicative of non-visual flicker.
- The risk assessment is documented with photos to check the gaze directions of several employees. Permission to take photos is obtained from the employer.
- The risk assessment is also based on the following regulations: 'AFS 2023:10', AFS 2023:11', 'AFS 2023:12' and 'AFS 2023:1'.

Execution and results

The general lighting is set to ca. 80% of maximum intensity during the risk assessment. According to the production specifications, the maximum level for the lighting is 700 lux. There is no panel lighting or suspended luminaires in the facility. The measurements are performed in the middle of the day in May, with daylight screening on the windows. The employees' ages range from 25 to 65. Both men and women work in the office. Some of the employees report that they want to have full illuminance from the ceiling luminaires so that they can see keyboards and display screens well, while others want to 'lower the lighting', as they put it. Others report experiencing glare and headaches, but have no direct opinions on the illuminance, with which they say that they are satisfied.

The identified risks and consequences are then risk-level rated in terms of injuries/symptoms and identified visual environment; see Tables 10 and 11 in these guidelines.

Table 14. Description and assessment of identified risks.

	Description of risk	Risk level
1	Twenty-five employees respond to the visual symptoms index and neck/shoulder symptoms questionnaire, with half of them reporting symptoms at work. These include visual symptoms, headache and neck/shoulder symptoms that occur all the way from occasionally to daily, and their experiences also range from insignificant to pronounced symptoms. Visual symptoms index and musculoskeletal symptoms or headache are reported in table form in the final ergonomics report.	● (red)
2	lluminance measurements vary among the various display-screen workstations. The illuminance in the central, close-up and peripheral fields of view varies by roughly 200 lux both over and under the respective recommended values of 500, 300 and 100 lux. The uniformity value indicates uneven lighting. Nine employees report glare.	● (red)
3	Daylight at the straight desks is assessed as being correct, but the daylight does not enter from the side in connection with the groups of three, but rather from the front or obliquely from behind and toward the display screens. Daylight screens are present in the form of blinds and curtains. Some risk of glare is present if the daylight screens are not used correctly.	● (orange)
4	Non-visual flicker from the LED lighting cannot be detected by measuring with the app *Ljus* or a smartphone camera. Information is also lacking, both in the product specifications and on the LED ceiling luminaires, as to whether the drivers use amplitude or pulse-width modulation.	● (green)
5	The luminance values indicate glare, as does the hat-test, primarily among the employees seated in groups of three. The visual ergonomic risk assessment indicates that direct glare from the recessed LED luminaires is considered to be the main cause of the problems.	● (red)
6	In this workplace, it is noted that a number of employees lack knowledge about working at a display screen, e.g. how to adjust the screen brightness and contrast, and how high the screen should be positioned in relation to the gaze angle. The gaze angle is noted as being below 20° for the majority of employees studied.	● (red)
7	Numerous employees have not undergone an eye examination in over five years.	● (red)

Remedial measures and recommendations in order of priority

Replace the recessed luminaires (LED ceiling panels) with well-shielded suspended luminaires and adjust them for the respective display-screen workstations. The luminaires must emit both upward and downward light that can be adjusted individually with a dimmer and thus tailored to individual needs. When selecting suspended lighting, remember to create a proper light distribution curve based on placement; the recommendations call for 70% upward- and 30% downward-shining light.

1. It is recommended that the workstations be arranged in rows, so that the suspended luminaires can be deployed easily in the open-plan office.
2. Train employees and new hires in visual ergonomics and working at display screens.
3. Perform both organisational and individual ergonomic risk assessments regularly.
4. Make sure that the employees undergo eye examinations regularly, and whenever they are experiencing problems or degraded vision.
5. Purchasing table luminaires is not recommended as a suitable solution, as direct glare from the general lighting from the LED ceiling panel luminaires is considered to be the main reason for the lighting problems.

Execution, results and proposed remedial measures are documented in a report submitted to the supervisor and the safety representative. A follow-up date is scheduled with the client two months after the report is submitted.

Follow-up

A joint follow-up by Occupational Health Services and the supervisor is carried out two months later. A decision has then been made that all the LED ceiling panels are to be replaced, and that the furnishings are to be changed so that they are arranged in rows in the space. Occupational Health Services is given the new task of assisting in positioning the furniture and luminaires properly, and in choosing the luminaires. Occupational Health Services is also tasked with training the employees in basic visual ergonomics/ergonomics for screen work in order to prevent musculoskeletal injuries.

The overall assessment over an entire workday is that there is a high risk (red) that one or more employees will develop musculoskeletal symptoms, headache or visual symptoms in the short or long term.

With the measures implemented, the risk rating is lowered to low risk (green).

Case 3: Visually demanding dental work at various distances

Case and questions

A department manager in the dentistry field contacts Occupational Health Services after an employee complains of recurring neck pain and daily headaches in an employee performance appraisal. The employee and manager suspect that the problems are due to work, as the employee has no other confirmed medical disorders or problems. The employee works as a dentist, which involves examining and treating numerous patients each day, with the work being done in oral cavities alternating with the dentist having to switch their gaze to a display screen at regular intervals. An ergonomist is assigned the case.

Preparations

To gain deeper insight into how the dentist's workday looks and the problems that they experience, the ergonomist decides to conduct a risk assessment of the work, supplemented with an interview with the dentist at the workplace.

The ergonomist chooses to use the following method and equipment:

- Visual ergonomic risk assessment based on the *Simple lighting/visual ergonomics checklist for non-specialists* (Prevent)
- Hat-test
- Interview with help of the *Visual ergonomics questionnaire with visual symptoms index*
- HARM – Hand-Arm-Risk-assessment Method
- Photos and measurements of neck angles using the Photo Measure Lite app
- Simple lighting measurements using Work Environment Authority's *Ljus* app
- The risk assessment is also based on the following regulations and report: 'AFS 2023:10', AFS 2023:11', 'AFS 2023:12', '2023:15', and 'AFS 2023:1', Report no. 18 Intervention levels for musculoskeletal injury, Occupational and Environmental Medicine, South Healthcare Region.

Execution and results

At the physical meeting, the ergonomist poses questions derived from the chosen method. The dentist demonstrates how their most common work operations are performed.

- The frequency of the number of examinations/treatments performed during a normal workday is noted.
- The dentist reports feeling stressed.
- The dentist works sitting down when working in a patient's oral cavity, as well as when working at the display screen. They sit with their back straight on a saddle chair, and keep their back straight. Their head is inclined forward 50° while they work. The viewing distance is noted to be roughly 35 centimetres between eyes and oral cavity.

- The mask that is worn throughout the treatment sits high up on the bridge of the nose, restricting the dentist's field of view.
- The display screen sits to the right on a fixed screen module, with the result that the neck is almost fully rotated when the dentist looks at the screen from the side.
- The distance to the display screen during this operation is roughly two metres from the eye. The dentist works with an upward gaze direction to view the screen, as the upper edge of the screen is above eye level, and the neck is then bent backward roughly 10°.
- The dentist wears protective glasses.

The identified risks and potential consequences are then risk-level rated with regard to injuries/symptoms and identified visual environment; see Tables 10 and 11 in these guidelines.

Table 15. Description and assessment of identified risks.

	Description of risk	Risk level
1	Visual ergonomics checklist for non-specialists and interview indicate risk of direct glare when the dentist looks at the display screen at an oblique upward angle.	●
2	The illuminance measurement with the app Ljus indicates too much light on the display screen. Additional and more precise lighting measurements are recommended in multiple treatment rooms in connection with positioning of the display screens. The illuminance on the screen keyboard, to which the dentist directs their gaze from a distance of two metres, is ca. 800 lux on this occasion.	●
3	Risk assessment as per HARM indicates static stress with high-frequency hand vibrations, which is an increased stress factor on the arm/shoulder/neck. Action values for hand vibrations are not found to be exceeded. In-depth risk assessment for hand-intensive work and hand vibrations is recommended.	●
4	The musculoskeletal problems in the neck are considered to be associated with working in oral cavities, based on Intervention levels for musculoskeletal injury and 'AFS 2023:10'. Forward bending is found to occur 10% of the workday, with a forward inclination of 30–50° = average/peak stress for forward inclination of the head. The headaches and cervical stress are believed to be associated with glare during screen work. Static muscle exertion occurs with tensed shoulders in connection with precision work in oral cavities, and with a backward inclination of the neck when the dentist looks at the display screen.	●
5	Several interacting risk factors of a musculoskeletal ergonomic and visual ergonomic nature were detected during the foregoing risk assessment. Stress also arises as a result of numerous examinations/treatments per day.	●
6	Unfamiliarity with the proper technique for working in an oral cavity is documented, as an upper forward inclination of the head near the cervical spine is present, while the mask is mispositioned and restricts the field of view.	●

Remedial measures and recommendations

- Offer the dentist and their colleagues prismatic glasses, care of their employer.
- Provide individual coaching in working techniques, e.g. point out forwarding bending of the upper neck, how to work better with relaxed shoulders and unstressed hands/lower arms, and how to position masks so that the field of view is not restricted.
- Describe how and how often to correctly position the patient, based on working posture and visual comfort.
- Move the display screen, or mount it on an adjustable stand to avoid neck rotation. When moving/adjusting the display screen, make sure to position it so that no glare arises due to reflected light.
- Vary working postures by alternating between sitting and standing when working in an oral cavity is combined with screen work. The head need then not rotate fully when the gaze needs to switch between different directions, but rather the entire body can be used for that motion.
- No risk assessment regarding hand vibrations and/or hand-intensive work as per 'AFS 2023:15', which concerns medical check-ups, has been performed in the department, and such an assessment is recommended to determine whether work environment measures should be implemented, or whether medical check-ups should be arranged for the employees as part of the Systematic Work Environment Management. Occupational Health Services can provide support here.
- A visual ergonomic and musculoskeletal ergonomic risk assessment of the entire department, including light and lighting measurements, is recommended to review every employee's working situation and gain an overall grasp of the situation by going through the entire workplace.
- Ongoing working-technique coaching and training are recommended for new hires as part of their workplace orientation.
- Continue as before with safety tours focused on the organisational and social work environment.

Execution, results and proposed remedial measures are documented in a report provided to employees and supervisor. Follow-up date scheduled for eight weeks later.

Follow-up

Upon follow-up it is found that a number of remedial measures have been implemented at the individual level, and that the employee has fewer neck problems, but still gets headaches several times a week. It is also found that the department manager, safety representative and department employees jointly discussed various types of risk assessments at a workplace meeting following this risk assessment, and that Occupational Health Services will be requisitioned to perform a visual and musculoskeletal ergonomic risk assessment at the department level. This will also include an in-depth risk assessment of hand vibrations and hand-intensive work to determine whether arranging for medical check-ups in their working lives would be beneficial, and also to tie their action plan to any newly discovered work environment risks. An ergonomist and a work environment engineer from Occupational Health Services plan to handle this task together.

The overall assessment over an entire workday is that there is a high risk (red) that one or more employees will develop musculoskeletal symptoms, headache or visual symptoms in the short or long term.

With the measures implemented, the risk rating is lowered to low risk (green).

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Appendices

Appendix 1. Terms and definitions

General terms

Visual ergonomics aims to balance human visual capabilities with the visual demands of specific work tasks. This balance is achieved by understanding the human visual system and analysing task-specific visual demands. Visual ergonomics includes how access to daylight, indoor lighting, glasses, and job tasks are designed to ease visual strain. The International Ergonomics Association (IEA) defines visual ergonomics as follows: *Visual ergonomics is the multidisciplinary science concerned with understanding human visual processes and the interactions between humans and other elements of a system. Visual ergonomics applies theories, knowledge and methods to the design and assessment of systems, optimising human wellbeing and overall system performance. Relevant topics include the visual environment, such as lighting; visually demanding work and other tasks; visual function and performance; visual comfort and safety; optical corrections and other assistive tools. (https://iea.cc/member/visual-ergonomics/) (135)*

Visual fatigue refers to degraded visual function that is presumed to be due to overuse of the eye. The symptoms include a sense of eye weakness or tired eyes, often in combination with musculoskeletal symptoms stemming from the neck and shoulder region. According to conventional terminology, there is no specific sign or distinctive symptom that indicates the presence of visual fatigue. An alternative usage of the term 'visual fatigue' is that it refers to something a person can experience. (38, 136)

Glossary of terms

Accommodation: adaptation of the eye lens for seeing at different distances; varies with age, see presbyopia.

Anthropometry: the study of measurements of the human body.

Astigmatism: when the curvature of the cornea is not uniform over its entire surface, with the result that light enters and is refracted to differing extents from different parts of the cornea.

Binocular vision: when the eyes cooperate, and a single and clear image of any object being looked at falls on the foveae of both eyes.

Central fovea of retina: central pit at the very back of the eye, where photoreceptors specialised for high resolution and colour vision are situated.

Ciliary muscle: inner eye muscle that regulates the refractive power of the lens.

Colour rendering: The ability of a light source to reveal the colours of various objects in comparison with an ideal or natural light source. Expressed as CRI or R_a index: colour rendering index, on a scale from 0 to 100, where 100 indicates optimum colour rendering.

Colour temperature: The colour temperature of a light source is measured in Kelvin (K). Comfortable work lighting typically ranges from 3 000 to 6 500 K, depending on individual preferences. A low colour temperature yields warm light, while a higher colour temperature yields a cooler light.

Contrast: the difference in intensity between light and dark areas in an image.

Convergence: a simultaneous inward movement of both eyes toward each other, to achieve or maintain binocular vision when focusing on a closer object.

Convergence insufficiency: Reduced ability to turn the eyes inward when looking at a nearby object; can lead to tired eyes, pain in and around the eyes, headache, and double vision.

Digital Vision Syndrome: a common group of symptoms associated with demanding computer work.

Double vision (diplopia): Often arises in connection with fatigue or when the eyes are overexerted. Often due to hidden phoria that is difficult to compensate for. The symptoms of phoria may increase with tiredness.

Efficacy/Light output (lm/W): a value that indicates how efficiently a light source converts energy into visible light.

Flicker: Light intensity variation over time (note that this definition applies in this report. International definition of flicker: term for a temporal light artefact entailing that variation in light intensity is observable over time, and visible without moving either the eye or the light source. Can be observed when the frequency of the light source's variation in intensity is below roughly 80 Hertz (CIE 2016)).

IC classification (European Standard EN 62262): International classification of protection against mechanical stress provided to electrical equipment by a housing.

Illuminance: the light that strikes/falls on a given surface (unit: lumen/m^2 or lux (lx)).

IP (Ingress Protection): A two-digit classification of the degree of protection against access to electrified components, and how water- and dust-proof the product is as per the following:

1. First digit

0. No protection
1. Childproof against objects larger than 50 mm
2. Childproof against objects larger than 12 mm
3. Childproof against objects larger than 2.5 mm
4. Childproof against objects larger than 1 mm
5. Dust-protected
6. Dust-tight

2. Second digit

0. No protection
1. Protected against dripping water
2. Protected against dripping water. The device cannot tilt more than max. 15° from its normal angle
3. Protected against trickling water. Max. angle 60°
4. Protected against trickling water from all angles
5. Protected against pouring water from a nozzle
6. Protected against heavy downpour of water (nozzle, sea, etc)
7. Can be immersed in water temporarily without sustaining damage
8. Suitable for prolonged immersion in water
9. Exposure to high-pressure sprayed hot water from different angles

IP69K: protection class intended for applications and environments which require regular intensive cleaning and can tolerate extremely harsh treatment.

ipRGC: Abbreviation for the light-sensitive ganglion cells in the retina of the eye, detected among millions of vision cells in 2002 (Intrinsic photosensitive Retinal Ganglion Cells).

LED (Light Emitting Diode): A diode that emits monochrome light under a forward electrical current. LEDs come in many different colours at present, as well as cool white and warm white.

Lumen (lm): The unit of light flow, with the unit symbol lm. The intensity of a light source is measured in candela.

Luminance: the light reflected from a surface (e.g. a desktop), or the light that a glowing surface emits (e.g. from a display screen) (unit: candela/m2, cd/m^2).

Luminance ratio: Indicates the relationship of the work area to the immediate surroundings. This ratio must not exceed 20:1, as otherwise there will be a high risk of glare.

Luminance ratios: Large differences in the luminance ratios are often the cause of glare. To avoid this, luminance ratios between the work area, the immediate surroundings and the outer surroundings of roughly 5:3:1 are recommended. This means that the luminance must be approximately five times higher in the work area than in the outer surroundings, and roughly three times higher in the immediate surroundings than in the outer surroundings.

Lux: The unit of illuminance. One lux (lx) is defined as one lumen per square metre (lm/m^2).

Melatonin: A hormone secreted by the pineal gland in the rear of the brain. Melatonin secretion is affected by light, so that melatonin levels are higher at night and lower during the day. The hormone plays an important role in regulating the circadian rhythm.

Modulation depth: The relation between maximum and minimum light intensity variation over time, calculated as (A-B)/(A+B), where A is maximum, and B is minimum (CIE 2016).

Myopia: near-sightedness, a refractive error in which parallel beams are focused at a point in front of the retina when the eye is in accommodative rest.

Near point of convergence: The nearest point at which the eyes can converge while retaining a single image (i.e. without double vision).

Non-visual flicker: The light intensity over time that is not visible to the human eye (note that this definition applies in this report). In strictly scientific terms, one speaks instead of subliminal light artefacts.

Phantom array effect: The name of a temporal light artefact that can arise during the short time in which eye movement is underway, in the form of observable punctiliar traces of the light source. Observable at very high frequencies (CIE 2016).

Presbyopia (geriatric vision): The lens of the eye loses elasticity and accommodation decreases, resulting in impaired sight at close range, which requires correction. Arises gradually with advancing age from 40 on.

Visual ergonomic productivity emphasise that productivity improvements will come when the workers' mental and physical health is satisfied, which will ensure that long-term performance is both high and sustainable. A healthy economic perspective on visual ergonomic productivity recognizes efficiency and output growth alongside sustainability and human well-being, ensuring gains that can be maintained and shared over the long term.

PstLM: Measurement standard for measuring flicker up to and including 90 Hz. As of September 2021, PstLM may not exceed a value of 1.

PWM (Pulse Width Modulation): A technique for dimming LEDs in which the light is constantly turned fully on or off, usually at frequencies of 100 Hz and higher. This produces flicker.

Reflectance: Reflectance is the property of a surface having to do with its ability to reflect light. The reflection factor is the dimensionless parameter used for reflectance, which is measured either as an index (0–1) or as a percentage (0–100 %).

RGB: Red/Green/Blue. Mixing these different colours makes it possible to produce many colour combinations, and it is also possible to cause a diode to glow white by mixing them correctly.

Stress: The term 'stress' can be used in different ways. Analogous with the use of the physical term, stress can denote working conditions that create undesirable mental or physical strain. Stress according to this view is an exposure. In other contexts, stress is used to denote a mental or physiological response pattern and reaction to demanding work conditions. Stress according to this view is a response.

Stroboscopic effects: The term for a temporal light artefact (stroboscopic pattern) which can arise when an object is in motion in light whose intensity is varying over time, or if the light source itself is moving. Observable between light-source intensity variations of from 80 to 2 000 Hertz (CIE 2016).

Stroboscopic Visibility Measure (SVM): Measure of stroboscopic effects up to and including 2 000 Hz. SVM may not exceed 0.4.

UGR (Unified Glare Rating): an international method for calculating an index for uncomfortable glare. The classification ranges from 5 to 40, with low numbers indicating low glare.

Uniformity value: Expressed as U_0 and is the lowest measured (darkest) value in the work area divided by the mean value for that same work area. The uniformity value can be a value between 0 and 1.

Visual acuity: Resolution capacity, i.e. the eye's ability to distinguish resolvable detail with and without correction. An individual's ability to see has to do with their visual acuity (or visus) and the ocular function working together with the light in the visual environment. Visual acuity refers to how well an individual can see (which row they can read at the optometrist); ideal visual acuity is 1.0, and the limit for a driving licence is usually 0.5.

Visual flicker: light intensity variation detectable by the human eye.

Appendix 2. Lighting recommendations for some different environments

The tables published in Appendix 2 is reproduced from a part of the Standard SS-EN 12464-1:2021 with the proper permission granted to the Swedish Agency for Work Environment Expertise by the Swedish Institute for Standards, which is the owner and copyright holder of the Standard(s), and also sells the complete Standard(s) at www.sis.se, Tel. +46 8 555 523 10. The numbering of the tables corresponds to that in the Standard.

Table 12 — General areas inside buildings – Store rooms, cold stores

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0{,}10$			
12.1	Store and stockrooms	100	150	0,40	80	25	50	50	30	200 lx if continuously occupied.
12.2	Dispatch packing handling areas	300	500	0,60	80	25	100	50	30	
12.3	Larder	200	300	0,40	80	25	-	-	-	Sufficient vertical illuminances shall be applied to shelving
For Logistics and warehouses – see Table 13 — Logistics and warehouses.										

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 13 — Logistics and warehouses

Ref. no.	**Type of task/ activity area**	**$\bar{E}_m$ lx**		**U_o**	**R_a**	**R_{UGL}**	**$\bar{E}_{m,z}$ lx**	**$\bar{E}_{m,wall}$ lx**	**$\bar{E}_{m, ceiling}$ lx**	**Specific requirements**
		required[a]	**modified[b]**				**$U_o \geq 0,10$**			
13.1	Unloading / loading area	200	300	0,40	80	25	50	50	30	
13.2	Packing / grouping area	300	500	0,50	80	25	100	100	30	
13.3	Configuration and rehandling	750	1000	0,60	80	22	150	150	30	
13.4	Open goods storage	200	300	0,40	80	25	50	50	30	
13.5	Rack storage - floor	150	200	0,50	80	25		–	30	Illuminance at floor level, R_{UGL} only in the viewing direction of the luminaire.
13.6	Rack storage - rack face	75	100	0,40	80	–	–	–	–	On aisle rack face. Band of 1,0 m may be excluded from the perimeter (see 5.4).
13.7	Central logistics corridor (heavy traffic)	300	500	0,60	80	25	100	100	30	
13.8	Automated zones (unmanned)	75	100	0,40	80	25				

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 19 — Industrial activities and crafts – Electrical and electronic industry

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m, ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0{,}10$			
19.1	Cable and wire manufacture	300	500	0,60	80	25	100	100	50	
19.2	Winding:									
19.2.1	- large coils	300	500	0,60	80	25	100	100	50	
19.2.2	- medium-sized coils	500	750	0,60	80	22	150	150	75	
19.2.3	- small coils	750	1000	0,70	80	19	150	150	100	
19.3	Coil impregnating	300	500	0,60	80	25	100	100	50	
19.4	Galvanising	300	500	0,60	80	25	100	100	50	
19.5.	Assembly work:									
19.5.1	- rough, e.g. large transformers	300	500	0,60	80	25	100	100	50	
19.5.2	- medium, e.g. switchboards	500	750	0,60	80	22	150	150	100	
19.5.3	- fine, e.g. telephones, radios, IT equipment (computers)	750	1 000	0,70	80	19	150	150	100	
19.5.4	- precision, e.g. measuring equipment, printed circuit boards	1 000	1 500	0,70	80	16	150	150	100	
19.6	Electronic workshops, testing, adjusting	1 500	2 000	0,70	80	16	150	150	100	

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 26 — Industrial activities and crafts – Metal working and processing

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m, ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0{,}10$			
26.1	Open die forging	200	300	0,60	80	25	50	50	30	
26.2	Drop forging	300	500	0,60	80	25	75	75	30	
26.3	Welding	300	500	0,60	80	25	75	75	30	
26.4	Rough and average machining: tolerances ≥ 0,1 mm	300	500	0,60	80	22	75	75	30	
26.5	Precision machining; grinding: tolerances < 0,1 mm	500	750	0,70	80	19	150	150	75	
26.6	Scribing; inspection	750	1000	0,70	80	19	150	150	100	
26.7	Wire and pipe drawing shops; cold forming	300	500	0,60	80	25	75	75	30	
26.8	Plate machining: thickness ≥ 5 mm	200	300	0,60	80	25	50	50	30	
26.9	Sheet metalwork: thickness < 5 mm	300	500	0,60	80	22	75	75	30	
26.10	Tool making; cutting equipment manufacture	750	1 000	0,70	80	19	150	150	75	
26.11	Assembly:									
26.11.1	- rough	200	300	0,60	60	25	50	50	30	
26.11.2	- medium	300	500	0,60	80	25	75	75	30	
26.11.3	- fine	500	750	0,60	80	22	150	150	75	
26.11.4	- precision	750	1 000	0,70	80	19	150	150	100	
26.12	Galvanizing	300	500	0,60	80	25	75	75	30	
26.13	Surface preparation and painting	750	1 000	0,70	80	25	150	150	100	
26.14	Tool, template and jig making, precision mechanics, micro- mechanics	1 000	1 500	0,70	80	19	150	150	100	

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 32 — Industrial activities and crafts – Vehicle construction and repair

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0{,}10$			
32.1	Press shop - large parts	300	500	0,60	80	25	100	50	30	
32.2	Press shop - visual inspection	500	750	0,60	80	22	150	50	30	
32.3	Body work and assembly - automatic line	300	500	0,60	80	25	100	50	30	
32.4	Body work and assembly - manual welding	500	750	0,60	80	22	150	50	30	
32.5	Painting, spraying chamber, polishing chamber	750	1 000	0,70	80	22	150	150	30	
32.6	Painting, inspection, touch-up and polishing	1 000	1 500	0,70	90	19	150	150	30	4 000 K ≤ T_{cp} ≤ 6 500 K
32.7	Upholstery manufacture (manual)	1 000	1 500	0,70	80	19	150	50	30	
32.8	Detailing: - Subparts assembly (doors, dashboard, upholstery) - Underchassis assembly - Motor and mechanical assembly - Final assembly conveyor line	750	1 000	0,70	80	22	150	50	30	
32.9	Detailing: - work with electronics	750	1 000	0,60	90	22	150	50	30	
32.10	Final inspection	1 000	1 500	0,70	90	19	150	150	30	4 000 K ≤ T_{cp} ≤ 6 500 K for recognition of colours
32.11	General vehicle services, repair and testing	500	750	0,60	80	22	100	50	30	Consider local lighting.

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 34 — Offices

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0,10$			
34.1	Filing, copying, etc.	300	500	0,40	80	19	100	100	75	
34.2	Writing, typing, reading, data processing	500	1 000	0,60	80	19	150	150	100	DSE-work, see 5.9 Room brightness, see 6.7 and Annex B Lighting should be controllable, see 6.2.4. For smaller cellular offices the wall requirement applies to the front wall. For other walls a lower requirement of minimum 75 lx could be accepted.
34.3	Technical drawing	750	1 500	0,70	80	16	150	150	100	DSE-work, see 5.9 room brightness, see 6.7
34.4	CAD work stations	500	1 000	0,60	80	19	150	150	100	DSE-work, see 5.9.
34.5.1	Conference and meeting rooms	500	1 000	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4.
34.5.2	Conference table	500	1 000	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4.
34.6	Reception desk	300	750	0,60	80	22	100	100	75	If reception desk includes regular work station tasks these should be lit accordingly.
34.7	Archiving	200	300	0,40	80	25	75	75	50	

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 44 — Educational premises – Educational buildings

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0,10$			
44.1	Classroom - General activities	500	1 000	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4, for different activities and scene settings. For classrooms used by young children, an Ēm required of 300 lx may be used by dimming (see 5.3.3). Ambient light should be considered, see Annex B, room brightness, see 6.7.
44.2	Auditorium, lecture halls	500	750	0,60	80	19	150	150	50	Lighting should be controllable, see 6.2.4, to accommodate various A/V needs, room brightness, see 6.7.
44.3	Attending lecture in seating areas in auditoriums and lecture halls	200	300	0,60	80	19	75	75	50	Reduction by dimming. DSE-work, see 5.9.
44.4	Black, green and white boards	500	750	0,70	80	19	-	-	-	Vertical illuminances. Specular reflections shall be prevented. Presenter/teacher shall be illuminated with suitable vertical illuminance.
44.5	Black, green and white boards in auditorium and lecture halls	500	750	0,60	80	19	-	-	-	Vertical illuminances. Specular reflections shall be prevented. Presenter/teacher shall be illuminated with suitable vertical illuminance.
44.6	Projector and smartboard presentation	-	-	-	-	-	-	-	-	1. Lighting should be controllable, see 6.2.4. 2. Specular reflections shall be prevented. 3. 200 lx vertically behind (around) screen. 4. Direct lighting on screen when displaying content shall be avoided
44.7	Display board	200	300	0,60	80	19	-	-	-	Vertical illuminances

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0,10$			
44.8	Demonstration table in auditoriums and lecture halls	750	1 000	0,70	80	19	-	-	-	
44.9	Light on teacher / presenter	-	-	-	80	-	150	-	-	At 1,6 m above the floor. Suitable vertical illuminance.
44.10	Light on podium area	300	500	0,70	80	-	-	-	-	Illuminance should be vertical in direction of audience, Lighting should be controllable, see 6.2.4, to accommodate various A/V needs.
44.11	Computer work only	300	500	0,60	80	19	100	100	75	DSE-work, see 5.9, lighting should be controllable, see 6.2.4, room brightness, see 6.7
44.12	Art rooms in art schools	750	1 000	0,70	90	19	150	150	100	Lighting should be controllable, see 6.2.4. Ambient light should be considered, see Annex B, room brightness see 6.7. 4 000 K ≤ T_{cp} ≤ 6 500 K
44.13	Technical drawing rooms	750	1 000	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4. Ambient light should be considered, see Annex B, room brightness see 6.7.
44.14	Practical rooms and laboratories	500	750	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4. Ambient light should be considered, see Annex B, room brightness see 6.7.
44.15	Handcraft rooms	500	750	0,60	80	19	150	100	100	Lighting should be controllable, see 6.2.4. Ambient light should be considered, see Annex B, room brightness see 6.7.
44.16	Teaching workshop	500	750	0,60	80	19	150	150	100	Lighting should be controllable, see 6.2.4. Ambient light should be considered, see Annex B, room brightness see 6.7.

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx		U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
		required[a]	modified[b]				$U_o \geq 0{,}10$			
44.17	Preparation rooms and workshops	500	750	0,60	80	22	150	150	100	Lighting should be controllable, see 6.2.4. Ambient light should be considered, see Annex B, room brightness see 6.7.
44.18	Entrance halls	200	300	0,40	80	22	75	75	50	
44.19	Circulation areas, corridors	100	150	0,40	80	25	50	50	30	Horizontal illuminance floor level.
44.20	Stairs	150	200	0,40	80	25	50	50	30	Horizontal illuminance at floor level.
44.21	Student common rooms and assembly halls	200	300	0,40	80	22	75	75	50	
44.22	Teachers rooms	300	500	0,60	80	19	100	100	50	For office work see Table 34 –Offices.
44.23	Library: bookshelves	200	300	0,60	80	19	-	-	-	Vertical illuminance on shelves. For dedicated bookshelves lighting the R_{UGL} value does not apply.
44.24	Library: reading areas	500	750	0,60	80	19	100	100	50	See Table 41 – Places of public assembly – Libraries
44.25	Stock rooms for teaching materials	100	150	0,40	80	25	50	50	30	
44.26	Sports halls, gymnasiums, swimming pools	300	500	0,60	80	22	100	75	30	These requirements are only applicable for schools. For non-school use, training and competition, apply the specific requirements given in EN 12193.
44.27	School canteens	200	300	0,40	80	22	75	75	50	
44.28	Kitchen	500	750	0,60	80	22	100	100	75	

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 45 — Health care premises – Rooms for general use

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx required[a]	$\bar{E}_m$ lx modified[b]	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx ($U_o \geq 0,10$)	$\bar{E}_{m,wall}$ lx ($U_o \geq 0,10$)	$\bar{E}_{m,ceiling}$ lx ($U_o \geq 0,10$)	Specific requirements
45.1	Waiting rooms	200	300	0,40	80	22	75	75	30	
45.2	Corridors: during the day	100	200	0,40	80	22	50	50	30	Illuminance at floor level.
45.3	Corridors: cleaning	100	200	0,40	80	22	50	50	30	Illuminance at floor level.
45.4	Corridors: during the night	50	-	0,40	80	22	-	-	-	Illuminance at floor level.
45.5	Corridors with multi- purpose use (e.g. preexamination of patients)	200	300	0,60	80	22	75	75	50	Illuminance at task/ activity level.
45.6	Day rooms	300	500	0,60	80	22	75	75	50	
45.7	Elevators, lifts for persons and visitors	100	200	0,60	80	22	50	50	30	Illuminance at floor level.
45.8	Service lifts	200	300	0,60	80	22	75	75	50	Illuminance at floor level.
Too high luminances in the patients' visual field shall be prevented.										

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 48 — Health care premises – Examination rooms (general)

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx required[a]	$\bar{E}_m$ lx modified[b]	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx ($U_o \geq 0,10$)	$\bar{E}_{m,wall}$ lx ($U_o \geq 0,10$)	$\bar{E}_{m,ceiling}$ lx ($U_o \geq 0,10$)	Specific requirements
48.1	General lighting	500	750	0,60	90	19	150	150	100	4 000 K ≤ T_{cp} ≤ 5 000 K
48.2	Examination and treatment	1 000	1 500	0,70	90	19	150	150	100	4 000 K ≤ T_{cp} ≤ 5 000 K.

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

Table 54 — Health care premises – Operating areas

Ref. no.	Type of task/ activity area	$\bar{E}_m$ lx required[a]	$\bar{E}_m$ lx modified[b]	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx ($U_o \geq 0{,}10$)	$\bar{E}_{m,wall}$ lx ($U_o \geq 0{,}10$)	$\bar{E}_{m,ceiling}$ lx ($U_o \geq 0{,}10$)	Specific requirements
54.1	Pre-op and recovery rooms	500	750	0,60	90	19	150	150	100	
54.2	Operating cavity surround	1 000	1 500	0,60	90	19	150	150	100	The illuminance of the cavity area should be luminance balanced to the immediate surrounding.
54.3	Operating theatre	1 000	1 500	0,60	90	19	-	-	-	
54.4	Operating cavity	-	-	-	90	-	-	-	-	Apply specific requirements given in EN 60601-2-41:2009[4].

[a] required: minimum value
[b] modified: considers common context modifiers in 5.3.3

4 As impacted by EN 60601-2-41:2009/A11:2011 and EN 60601-2-41:2009/A1:2015.

Appendix 3. Protocol for measuring daylight and lighting

Workplace				
Date:			Time:	
Weather:	Sunny ☐	Partly clear ☐	Cloud ☐	No daylight ☐
Window faces:		Measurement instrument:		
Assessment made by:				

Computer work	External screen	Laptop	Tablet	Smartphone	In-built screen	Other
Type/number of screens:						
Size:						
Hours/day at screen:			Incident light on the screen (max. 200 lux):			
Viewing distance to screen:				Character size:		

	Yes	No	Remarks
Is the screen easy to read? Sharp contrasts/good edge definition?			
Screen properly positioned in relation to daylight/luminaires?			
Has the employee had an eye exam? When?			

Lighting conditions	Yes	No	Remarks
Is there satisfactory daylight? (AFS 2023:12, Ch. 5, Sec. 25)			
Is the view satisfactory? (AFS 2023:12, Ch. 5, Sec. 25)			
Is there a risk of glare from daylight?			
Is it possible to screen off troublesome daylight?			
Is there sufficient illuminance on the work surface?			
Correct light direction (from above/behind)?			
Are there any broken or dirty light sources?			
Does visual flicker occur in the surroundings?			
Is there any non-visual flicker?			
Is there a risk of direct glare from the luminaires?			
Is there glare or reflections from the work material?			
Is the colour rendering according to recommendations?			

Measured illuminance (lux – incident light)	#1	#2	#3	lux (mean)
Inner work area (central field of view) (average of at least 3 points)				
Outer work area (immediate area)				
Peripheral area				
Display screen (meter held at same angle as the display)				
Darkest surface in the work area				
Uniformity of Illuminance (darkest surface/average for inner work area)				

Measured luminance (cd/m^2 – reflected light)	#1	#2	#3	cd/m^2
Inner work area (central field of view) (average of at least 3 points)				
Outer work area (immediate surroundings)				
Peripheral area (outer surroundings)				
Luminance ratios: Recommended ratios = 5:3:1 (inner, outer, peripheral)				
Luminance ratio: Recommended maximum 20:1. *Calculation: average inner work area/average outer work area (immediate surroundings)*				

Appendix 4. Needs identification and activity mapping

Modified from Method Compendium by Rolfö (123).

The needs and activities of the enterprise need to be mapped in order for the lighting designer, lighting consultant or architect to be able to customise its lighting. Determine the **physical needs,** such as furniture, work equipment and technical equipment, **social needs,** such as discussions and meetings, and **organisational needs,** e.g. information and changeability. The activity mapping is done in steps by first identifying the various work activities being done, and then measuring their duration and frequency.

Step 1: Identify the needs

Determine the needs associated with various job tasks via focus group interviews with various work teams. Map the presence of any problems, disruptions, quality deficiencies, physically and mentally stressful situations, deficiencies in terms of interactions, etc. Document in particular those needs that are related to visual ergonomics.

Step 2: Prioritise the needs

Supplement the results from the focus group interviews with a questionnaire. All the employees will then be able to assess how important all of the needs that have come to light in the interviews are to them. Document the results.

Step 3: Map work activities

The activity mapping is done by first identifying the various work activities present and then measuring their duration and frequency. This can be done through observation, or by the individual employees.

Step 4: Compile needs and work activities

Separately report the work activities, their associated needs (in the form of facilities, technology, organisation), needs pertaining to wellbeing/work environment, and needs related to equipment.

Step 5: Journals

The results can be made more generally applicable and cover more people by using journals to explore in greater depth. Use the list of work activities generated in steps 3 and 4, and ask the employees to estimate, over two to five days, the time they have spent on the respective activities they engaged in. Separate the activities based on whether they were done alone, in small or large groups, whether they required light or heavy concentration, and where they were carried out.

Step 6: Assess the need for light

Discuss, in smaller groups, the needs for light in various work activities and for different employees, how any organisational changes will affect the need for light, and how individual health aspects should be handled. Document the results.

Step 7: Designate a lighting designer

Let the lighting designer, lighting consultant or architect share in the collected material and use it as a documentary basis for the future building.

Appendix 5. Workbooks – a method for describing job tasks

Modified from Method Compendium by Rolfö (123).

The Workbook Method offers employees a means of describing what is working well, and what needs improvement with respect to their own job tasks. Employees know a great deal about their own work environment and how it functions in their daily jobs. However, it is not always so easy to elicit this knowledge when gathered around a conference table. The workbook, in which pictures of the workplace can be commented on using colour codes, offers a simple method that makes it easier for employees to point out what is working well and in their daily jobs, and what is working less well.

Example workbook for process operators

Process operators at a small chemical plant were rarely involved in the work of the production engineering personnel, and only pressing safety issues were taken up with the management. A project team was created in connection with a major design change, and they chose to compile a so-called workbook together with the operators. The steps involved in this effort are described below:

Step 1: Tour and photography

The operators took the project team on a tour of the workplace. The project team asked the operators to point out key aspects, locations and processes. Everything was documented with photos, and finally the operators were asked to pick out the 12 most important pictures, which were then printed and glued into a physical workbook.

Bear in mind! Good pictures in this context are highly detailed and show people, environments and job tasks.

Step 2: The employees comment on the pictures

The workbook is displayed in the workplace for one workweek. The operators are encouraged to comment on the pictures, using different coloured pens. A green pen is used for things that should be retained in the new workplace, red is for things that need to be changed/solved in a better way, and yellow is for things that need to be taken into consideration. All the operators commented in the same book. This encouraged participation and offered an opportunity to expand upon and discuss one another's comments.

Step 3: Presentation of the workbook

A workbook is a document that requires the attention of the management and the project team. At this plant, the operators presented the workbook at a workshop a long with engineers and management. The pictures with comments compel the management and project team to concentrate on what the operators consider important.

Appendix 6. Photo safari

Modified from Method Compendium by Rolfö (123).

As a new hire in a workplace, one sees things with fresh eyes and thus naturally question things that may be self-evident to those who have been in the organisation for a while. The so-called *photo safari* method is based on this, and helps us to see our workplace with fresh eyes by visiting other workplaces similar to our own. Using the photo safari methods offers an excellent opportunity to analyse one's own workplace in its daily operations, or prior to a renovation.

How the photo safari method works (example)

Step 1: Preparations

A study was conducted in a government office to determine whether a participatory design dialogue could serve as a suitable planning method by allowing the employees to conduct a photo safari together with the design team. At a preparatory workshop, the employees choose a number of topics to which they would pay particular attention during the visits to the other workplaces. The topics chosen comprised the physical work environment, opportunities for collaboration, and the workplace design. The categories were documented in a handbook which the participants took with them on the visits.

Step 2: Find similarities and differences

The groups visited four workplaces which had just been given a new office design. The employees took part in the visits in small groups of three or four, and looked for differences and similarities between their own workplace and what they saw in those they visited.

Step 3: Photograph and chat

The visitors went round to each workplace and chatted with employees and their supervisors, observing, reflecting, and taking pictures. The topics selected earlier by the groups served as a concrete documentary basis for the photo safari. A natural platform was also established for contacts between the visitors and the employees in the visited workplaces. It was natural to ask questions, and to ask the employees in each workplace to point out the things they wanted to be captured in photographs.

Step 4: Presentation

Back at their own workplace, the groups presented their pictures to one another. Each group carefully reviewed what the others had noted during their visits. Differences were discussed, and ideas for a new office design were discussed on that basis.

Appendix 7. The improvement log

Modified from Method Compendium by Rolfö (123).

It happens that obstacles or problems in performing job tasks go unnoticed during the planning and design work. They may be noticed before or after moving into the new space. It can then be beneficial to capture such obstacles and problems as quickly as possible, along with any proposed solutions.

Obstacles can consist of factors that limit or hinder employees in performing their job tasks smoothly. Avoiding such obstacles can improve the work environment in both the existing facilities and the new/renovated ones. This method offers employees a means of influencing their future work environment easily, and without taking time away from the operations. The point is to be able to quickly report the problems and opportunities for improvement observed.

How the improvement log works:

WHAT: Detect obstacles:

Over one week, let the employees document and submit logs regarding:

- **Mess** – things perceived as messy, annoying or uncomfortable.
- **Routines** – routines that are not working optimally and are perceived as being extra stressful or unnecessarily time-consuming.
- **Solutions** – proposed reactive and proactive solutions pertaining to processes or the design of the facility.

HOW: Log via multiple channels:

Make it possible for the employees to submit logs describing obstacles and solutions at the same time as they arise. Give them the means of submitting their logs via various channels, such as **e-mail, answering machines, SMS, telephone, paper and pen, quality systems** or **incident-reporting systems**. Logs from all the channels are then compiled by a designated coordinator at the end of the week.

HOW: Structure, compile and feedback:

The received logs are compiled in a document, structured, and fed back to the workplace. A work environment expert can supplement with proposals where solutions are lacking. Document in an action plan and identify what is to be rectified and when it will be rectified. Follow up on the action plan.

Appendix 8. Example requirement specifications – industry

Requirement specifications, lighting systems for an industrial company X

An example of a demand specification follows below. The original version was obtained from a Swedish company, and is reproduced here in somewhat modified form. Observe that these internal requirements have been decided by the organisation and are therefore not necessarily in agreement with standards or other recommendations.

Documents

The documents apply in the following order of priority:

1. Boverket's Building Regulations – BBR (Compulsory regulations).
2. AFS 2020:12 Workplace design (Compulsory regulations).
3. TR Technical Guidelines for Properties/Electrical (Company-internal).
4. SS-EN 12464-1 Light and lighting – Workplace Lighting – Part 1: Indoor workplaces – Part 2: Outdoor workplaces (Recommendation).

General lighting guidelines

- During planning, the lighting may need to be adapted to the relevant premises and operations, in consultation with the user.
- The switching on of lighting must be well sectioned. Large spaces with multiple lighting sections must have their lighting layout displayed next to the location of the switches.
- Lighting rails (powered rails) for luminaires are installed in larger spaces used for workshops, processing, assembly, logistics surfaces, warehouses, etc. Installations are designed so that luminaires can be shifted and supplemented with new luminaires easily, and must be expandable by at least 20%.
- The light intensities (lx) specified in the attached tables may be exceeded by a maximum of 30%. Means of adjusting the light are recommended so that desired light intensities can be maintained over time.
- Colour temperature = 4 000 K (Kelvin) unless otherwise specified.

Illuminance guidelines

Illuminances (lx) for different environments must agree with the values stated in lighting standard SS-EN 12464-1:2021, which indicate the lowest mean illuminance ($\bar{E}_m$ lx) and uniformity ($U_o = \bar{E}_{min}/\bar{E}_m$) in effect within the portion of the workplace that comprises the defined work area.

The work area is defined as the partial area of the workplace where the visual job task is performed. The entire workplace is not usually counted as the work area. For example, the normal area of the work area in an office workplace is given as 0.6 m × 0.6 m.

The illuminances in the tables are intended for work under normal conditions, and for individuals with normal vision. In this industry, the illuminance in workplaces where work is done continuously for more than two hours shall not be below 200 lx.

Glare and colour rendering

- The UGR (Unified Glare Rating) method is used to assess uncomfortable glare directly from the luminaires in a lighting installation. The UGR value must not exceed the value in the relevant table in the lighting standard.
- Colour rendering requirements to enable the performance of a visual task and determine colours optimally are expressed via a so-called CRI or R_a index. A high index indicates good colour rendering.

For tables of lighting requirements, see European Standard, SS-EN 12464-1:2021 Light and lighting – Workplace Lighting – Part 1: Indoor workplaces (www.sis.se).

A selection of tables from the standard are also reproduced in Appendix 2 to this publication - Guidelines for visual ergonomics – Lighting and Vison in the Workplace.

Function and control

Lighting is controlled by means of a control system that can be connected to the central building management system at the company. The luminaires in spaces with incoming daylight should be dimmable and automatically adjustable.

Lighting control via logic relay and push-button(s)

Suggested examples as follows:

Monday–Friday 7:00 a.m.–6:00 p.m.

- *First push of the switch turns on the lighting, which is on from 7:00 a.m. to 8:00 a.m.*
- *Second push of the switch turns off the lighting.*
- *Third push of the switch turns on the lighting, which is on from 7:00 to 6:00 p.m., and so on.*
- *The lighting turns off automatically at 6:00 p.m.*

Monday–Friday 6:00 p.m –7:00 a.m. plus Saturdays and Sundays

- *First push of the switch turns on the lighting, and it is on for one hour.*
- *Second push of the switch turns off the lighting.*
- *Third push of the switch turns on the lighting, and it is on for one hour.*
- *And so on.*

The lighting can also be controlled by means of a daylight sensor that turns it off when a lot of daylight is coming in.

Emergency lighting and backup system

The documents take priority in the following order for emergency lighting, backup lighting and lighting systems for guiding signage:

1. Boverket's Building Regulations – BBR (Compulsory regulations).
2. AFS 2023:11 Workplace design (Compulsory regulations).
3. Fire protection description established for each project.
4. TR Technical Guidelines for Properties/Electrical (Company-internal).

In connection with the renovation or new construction of facilities with no fire protection description, a risk analysis must be arranged to address the need for emergency lighting, backup lighting, and lighting systems for guide signage.

Light sources must be of the LED type, with colour rendering of at least R_a 40.

Emergency lighting system

AFS 2023:12, Ch. 3, Sec. 60 provides that 'Escape routes that require lighting in order to enable safe escape must have emergency lighting that illuminates them adequately in the event of a power outage'.

BBR provides that emergency lighting must be present (see relevant enterprise classes) and describes how it is to be realised. In facilities and sites where BBR requires emergency lighting, it must be realised as per SS-EN 1838.

Emergency lighting of escape routes

At least 1 lx on floor surface along centre line of the escape route. At least 5 lx in stairways and at level changes. At least 50% of required illuminance within 5 seconds, and at least 100% within 60 seconds.

Emergency lighting for assembly areas for > 150 people

At least 1 lx on entire floor surface, except 0.5 m nearest the walls. Also applies to toilets for people with functional impairments. At least 50% of required illuminance within 5 seconds, and at least 100% within 60. Emergency lighting must be available immediately outside.

Emergency lighting for high-risk areas

Applies to spaces or surfaces with dangerous rotating machinery, corrosive chemicals, hot surfaces, etc.

The shortest duration is established with the employer. The illuminance maintained on the surface where the job task is performed in the high-risk area must be at least 1% of the required maintained illuminance for the job task, but it cannot be lower than 15 lx. The required illuminance must be achieved within 0.5 seconds.

Emergency lighting in industrial facilities, warehouses, etc.

Such premises normally fall into enterprise class 1 as per BBR and have no emergency lighting requirements. People in such facilities normally have a good knowledge of the space, can evacuate independently, and are expected to be awake.

Backup lighting in the form of LED lights is installed in spaces larger than 60 m^2.

Emergency lighting in substations

Rechargeable handheld torches with LED light sources, kept in charging stations. It must be possible to choose full or half power; half power must be turned on automatically in the event of a power outage. Connected to backup-powered 230V wall outlet with lead and plug. Placed at escape door, 0.5 m above the floor.

System and functions

Emergency lighting must come on in the event of loss of power to the regular lighting, and shine for at least 60 minutes. Emergency lighting must be centrally powered via monitored battery backup.

Voltage 230V or 24V.

Emergency lighting must be controlled via under-voltage relay or an equivalent relay activated in the event of loss of power to the entire electrical control centre or lighting group.

Backup lighting system

Installed where operations need to continue or to enable appropriate shutdown measures in the event of a power outage in, e.g., production facilities. The backup power system is connected to backup power only; activation times of ca. 15 seconds are acceptable in the event of loss of power to the regular lighting. If the operation requires a shorter activation time, the backup lighting is connected to a battery-backed central emergency lighting system.

Appendix 9. Example requirement specifications – healthcare

Example 1: Requirement specifications – Circadian rhythm lighting for care units

An example of a demand specification follows below. The original version was obtained from a Swedish healthcare region, and is reproduced here in somewhat modified form. Observe that these internal requirements have been decided by the organisation and are therefore not necessarily in agreement with standards or other recommendations. The example has been prepared by Johan Niléhn.

Background

Circadian rhythm light on a care unit must meet both the requirements currently in place in a care unit and support the circadian rhythms of those who are in the unit by reinforcing the natural daylight coming in through windows. This means that both the colour temperature and intensity must be controllable.

Circadian rhythm light

Melanopic effect

To ensure a melatonin level with a good biological response, the health light must be specified with the following levels of Melanopic Equivalent Daylight (D65) Illuminance (EDI), $E_{v,mel}$, measured vertically at eye level and expressed in lux. This applies to all spaces where people are present round the clock.

Day: $E_{v,mel} \geq 250$ lx

Evening: $E_{v,mel}$ 25 – 100 lx

Night: $E_{v,mel} \leq 3$ lx

The Melanopic EDI ($E_{v,mel}$) value measured from a light source indicates how much illuminance from daylight (standardised D65) is needed to achieve the same melanopic effect as from the measured light source.

Flicker – TLM (Temporal Light Modulation)

The light should preferably be frequency-free, with no temporal light modulation. In the event of similar tenders, the one with the best performance should be prioritised.

The lighting solution's flicker must therefore here fulfil PstLM ≤ 1 (=50% of individuals can see this flicker) at all lighting levels and colour temperatures.

The lighting solution's stroboscopic effect must therefore here fulfil SVM ≤ 0.4 at all lighting levels and colour temperatures.

The PstLM and SVM requirements became the EU standard in 2021 for full load. However, most flicker occurs in connection with attenuation, with the result that the requirements in this example, have been expanded to apply to the entire dimming range for the system.

Note! The proper accepted international terminology for flicker, temporal light artefacts and temporal light modulation is used in these requirement specifications.

Glare

The luminaires must be designed to reduce the risk of glare. Sharp transitions can be avoided by using prismatic or slatted blinds, and/or by using indirect lighting obtained either via light shone over surrounding surfaces from the luminaires, or with the help of additional luminaires providing indirect lighting.

Intensity, colour rendering, and light colour

At 4 000 K, 1 000 lx must be achieved in rooms where emergency lighting (emergency lighting can be used when 1 000 lx is needed in emergency situations or when there are heavy visual demands) is a requirement. For other colour temperatures, the system must be able to provide sufficient light to support melanopic EDI as described above.

Colour rendering: it must be possible to achieve R_a>90 by pushing a button in the room/workplace. This need not be fulfilled during times when circadian rhythm light is in use.

The circadian rhythm light must fall within the range of 1 650 K–6 000 K, although other levels are acceptable as long as the foregoing Equivalent Melanopic Daylight requirement is met in hospital rooms and other areas that are in use round the clock.

The intensity of the night lighting must be at a level that enables normal night-time work to be done without the need for other configurations. Patient rooms must be able to go down to 5 lx, while corridors, etc. must be at 30 lx, as long as they are not affecting the amount of light inside patient rooms. Measurements are made 1 m above the floor.

The intensity and colour must be freely adjustable, with no negative effects on the luminaires and control units.

Colour temperature quality requirement

The luminaires' colour differences must be minimal, and should not be observable between different units during the service life of the luminaires. SDCM values for diodes must fall within class 1–3 as per CIE 1964.

Control

All luminaires must be connected so that they can be controlled individually or as a group. The grouping must be flexible, so that it can be adapted to future needs.

Control must be exerted based on a pre-programmed recipe (time-based light levels and colour temperatures), which must be adjustable and increase in number over time as new research and standards emerge. The recipes include unique intensity and light colour settings, as well as the ability to exclude the blue wavelengths.

The daily rhythm of the lighting must be managed automatically, so that the lighting follows the progression of the day. New curves must be programmed based on new knowledge that comes to light moving forward.

Preset recipes must be accessible via a keypad or the equivalent in the room.

It must be possible to make different choices via push buttons and/or control panels at each bed, as well as in other rooms with special functions, such as medication stations, etc.

All rooms must be controllable from a central unit stationed in an office.

Light must be manually dimmable. A reversing button must be present. The button may be physical, or virtual on a terminal.

Keypads for staff must be present in all care/examination rooms so that, for example, the emergency setting can be selected quickly. Emergency setting = 1 000 lx 4 000 K (colour temperature must be adjustable subsequently, if necessary, within the range of 3 000 K– 4 500 K).

The system must be able to exert control via motion sensors.

Control systems must have open interfaces, so that other units can be controlled using the installed control equipment.

It must be possible to adjust the light in increments that are not directly perceptible by the people present in the space.

Integration

It must be possible to troubleshoot the system via remote link and connection, and the installation is consequently subject to Region´s requirements.

It must be possible to install other manufacturers' luminaires, as long as they meet the requirement for the control system's communication standard (DALI/KNX/DMX).

Contrast with ceiling

The lighting must have the lowest possible contrast between luminaires and ceiling, as recommended by the Work Environment Authority. Suggested solutions involve the use of screens, up-down lights and/or prismatic blinds and, preferably, raking lights across the ceiling.

Hygiene

All visible components in the lighting system must meet Hygiene class 2, BOV 3rd edition with regard to wipeable surfaces.

Luminaires must be designed so that dust does not build up inside them.

Staff areas

It must be possible to install accommodation for a so-called 'light shower', in which the levels must be 2 000 lx of cold light, ca. 5 000–6 000 K, at eye level and with a timer so that a given number of minutes can be set; it must be integrated and centrally adjustable, based on the most recent available research findings.

General

All spaces that are to be used/visited round the clock must be equipped with circadian rhythm lighting.

Example 2: Requirement specifications – general lighting for surgery rooms

An example of a demand specification follows below. The original version was obtained from a Swedish healthcare region, and is reproduced here in somewhat modified form. Observe that these internal requirements have been decided by the organisation and are therefore not necessarily in agreement with standards or other recommendations. The example has been prepared by Johan Niléhn.

Background

According to the specification below, the illuminance must be at least 5 500 lx, and preferably 6 000 lx or higher for general lighting in the operating area, and 2 000 lx for the rest of the room. Lighting at this level means that the contrast differences between surgical wound and, for example, operating table stay below 20:1 when the surgical lamp is set at 110 000 lx or lower. The 20:1 ratio is a visual ergonomic limit value that one should strive to stay below.

Flicker - TLM (Temporal Light Modulation)

The light should preferably be frequency-free, free from temporal light modulation. In the event of similar tenders, the one offering the best performance should be prioritised.

The lighting solution's flicker must therefore here fulfil PstLM ≤ 1 at all lighting levels.

The lighting solution's stroboscopic effect must therefore here fulfil SVM ≤ 0.4 at all lighting levels.

The PstLM and SVM requirements became EU standard in 2021 for full load. However, most flicker occurs in connection with attenuation, with the result that the requirement in this example, have been expanded to apply to the entire dimming range for the system.

Note! The proper accepted international terminology for flicker, temporal light artefacts and temporal light modulation is used in these requirement specifications.

Control

All luminaires must be connected so that they can be controlled individually or as a group. The grouping must be flexible enough to enable adjustment so that people with different skills have good light for their tasks, regardless of the type of operation being performed.

Control must be exerted based on a pre-programmed recipe (time-based light levels and colour temperatures), which must be adjustable and increase in number over time as new research and standards emerge. The recipes include unique intensity and light colour settings, plus the ability to exclude the blue wavelengths.

The number of recipes, i.e. pre-programmed settings created for different surgical tasks (e.g. abdominal, iliac, etc.), will be more than eight, and probably significantly more, as different types of operations require different lighting. The supplier must take part and create and add new recipes upon request. The recipes must be selectable in a tree structure.

Control from the standard panels in the operating room must be prepared for.

Lighting must be manually dimmable. A physical and/or digital reset button for restoring earlier levels must be present.

The control system must have an open interface, so that it can be controlled by/ control other equipment.

Intensity and light colour

General lighting within the 3x3 m operating area at 5 500 lx (minimum) must be achievable at a working height of 0.9 m. The intensity must be adjustable for the type of work being done.

The rest of the premises must be able to achieve at least 2 000 lx, except for peripherally, i.e. 0.5. from the walls, where 1 000 lx is acceptable. Anaesthesia areas, with screens, must be considered peripheral areas, and be at 1 000 lx.

At least 500 lx must be achievable on walls and ceilings.

Preparations for dimming capacity down to 50 lx, at working height, must be made for all colour temperatures.

The colour temperature and intensity must be adjustable so that they track the illumination from the suspended surgical lamp. Current surgical lamp colour temperatures are at around 4 000 K.

The colour temperature must be adjustable within the range of 3 000–4 500 K.

The composition of the light from the various diodes must be adjustable so that the best nuances can be achieved for different display screen tasks, e.g. ultrasound images, laparoscopy, or endoscopy. Examples of such colour nuances include red and green, which are used in various types of keyhole surgery. Surgical lamps are not used in such procedures, and the relevant light levels are on the order of 300 lx down to 50 lx.

Colour rendering R_a>90 for white light.

Integration

The general lighting in the operating room must be integratable with the combi-display chosen by the Region so that the selected lighting recipe is displayed to ensure that the correct lighting for the task has been selected.

Contrast with ceiling

According to the recommendations from the Swedish Work Environment Authority, prismatic or slatted blinds should be used to prevent glare, at least for those luminaires which are in front of people working at display screens, and preferably for all luminaires.

Hygiene

All visible components in the lighting system must fulfil Hygiene Class 3, BOV 3rd edition, for wipeable surfaces.

Appendix 10. Light meter operation

There are different types of light meters intended to measure illuminance and luminance ratios. Light meters manufactured by Hagner are common in Sweden, and the operation of the two most common Hagner models is described here. The two models covered in the operating description are:

- Hagner S1–S4, which is used to measure illuminance, luminance of illuminated surfaces and reflectance in an existing facility by measuring the actual reflections on various surfaces, or the reflectance of proposed surfaces for a planned facility.
- Hagner Screenmaster, which is used to measure illuminance and luminance.

How to use the Hagner S1, S2, S3, S4 light meters

Start by selecting illuminance, ILLUM lux, or luminance, LUM cd/m^2, on the slider or toggle switch. See figure on the next page.

Illuminance is measured toward the round white surface on the external light sensor. Make sure that it is connected to the meter's detector input.

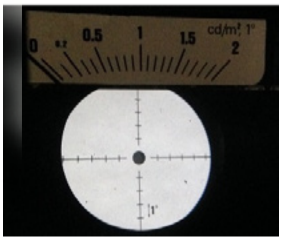
- When measuring, hold the sensor toward the incident light, without screening off the light shining on the white surface.
- Pull out the cable so that you can stand as far from the sensor as possible.
- Hold the measuring device at the angle required by the job task, i.e. horizontally toward a table surface, flat toward a computer display, or vertically toward a bookshelf, or toward a wall that forms the background of the work object.
- Move the meter about to get a good idea of where it is suitable to measure.
- Hold the meter at working height (desk height) during the measurement.

Illuminance is measured for all three work areas, i.e. the inner, outer and peripheral work areas. Measure at least three points in each area, and preferably more, then calculate the mean value for each work area.

Luminance is measured by looking through the meter at the object to be measured. The small black ring in the centre inside the meter shows the surface being measured (ca. 1°); see figure on next page.

Luminance is, like illuminance, measured for all three work areas, i.e. inner, outer and peripheral. At least three and a maximum of 10 points are measured for each area. Always note the highest and lowest measurement values. Pay particular attention to glaring surfaces and reflections.

Slider for selecting what is to be measured.



The Hagner S4 Light Meter measures both luminance and illuminance, and can be used to measure reflectance as well. Illuminance is measured via the external cell which is connected to the meter by a fibre-optic cable. Luminance is measured by looking through the meter and aiming it using the dot in the crosshairs on the measured surface; this meter is measuring the luminance at 1°.

Using these larger light meters, it is possible to measure a small surface at a greater distance (several metres) than with the Hagner Screenmaster, which has a measurement angle of 36°. This means that measurements of small areas cannot be performed with the Screenmaster since the instrument will shadow the enlightened area when held close to the measured surface. Because the luminance is almost constant regardless of distance, the reflection can be calculated; see next section.

Reflectance from, for example, a wall can be measured by measuring the luminance of the surface without casting a shadow on it, while being close enough not to include other details in the measured area. The instrument is then switched on and the amount of light striking the surface is measured. This yields the measurement values needed to calculate the reflection factor. Luminance times pi divided by illuminance yields the reflection factor; see formula:

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

L = Luminance (cd/m²)
E = Illuminance (lx)
ρ = Reflection factor (%)

Surface:	Luminance (cd/m²):	Illuminance (lx):	Reflection factor (%):
	Distance in cm:		

A Hagner S1–S4 can be used to measure the reflectance factor by using the instrument's luminance measurement. Set up a sheet of white copy paper on or across the surface whose reflection factor is to be determined. Both surfaces must be equally illuminated. Measure the luminance from the surface for which the reflection factor is being determined, and the luminance from the white paper. Calculate the reflection factor using the following formula:

$$\rho = \frac{L_y \times 0{,}9}{L_v}$$

L_y = luminance from the surface to be determined
L_v = luminance from the white paper
ρ = reflection factor from the surface to be determined

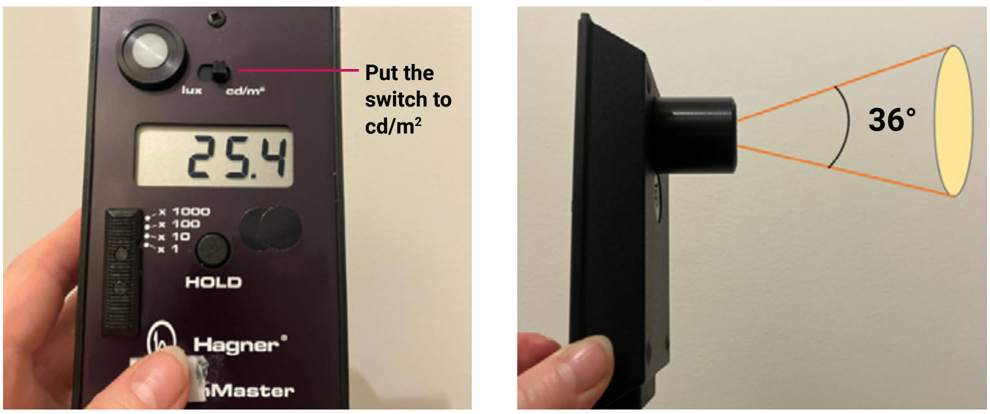
Hagner Screenmaster Light Meter

Start by selecting illuminance, ILLUM lux, or luminance, LUM cd/m^2, using the slider or toggle switch. See figure below.

Illuminance is measured toward the round white surface on the front side.

- When making the measurement, hold the sensor toward the incident light, without screening off the light.
- Hold the measuring device at the angle required by the job task, i.e. horizontally toward a table surface, flat toward the computer display, or vertically toward a bookshelf, or toward a wall that is forming the background for the work object.
- Hold the meter at working height (desk height) during the measurement.

Luminance: This light meter is designed mainly for measuring display screen luminance, which is measured by holding the meter directly toward the screen. The Screenmaster is not suitable for measuring the luminance of illuminated surfaces, as it often casts a shadow on the surface being measured, and the measurement values are then too low. Bear in mind that the lens at the front of the luminance meter has a measuring angle of 36°. This means that, the further from the surface it is held, the larger the surface whose average illuminance it measures. To measure a smaller surface, it is necessary to get quite close to the measured surface (sometimes just a few centimetres from the measured object).



Hagner Screenmaster.

Appendix 11. Summary of the planning process

A brief summary of the planning process in 'Light and Space' (in Swedish, Ljus och Rum) (137), somewhat modified.

Specify

Visual tasks
Which visual tasks are present?
How are the work surfaces best lit?

Safety
Could stroboscopic effects create risks in the work?
What risk zones and escape routes must be lit?

Analyse

Compulsory conditions

Legal requirements
Which legal requirements are relevant?

Financial requirements
Investment, operating and maintenance costs.

Physical requirements
Ambient requirements, temperature, electrical and magnetic fields.
Installation restrictions – recess depth or restrictions on luminaire size.

General conditions

Requirement specification
Which requirements/recommendations apply?

Energy efficiency requirements
Lighting control?

Quality requirements
Aesthetic, architectonic, and work environment-related.

Plan

Daylight and electric light
Possible to use incident daylight?

Sun screening
Are the windows designed to block sunlight when needed and radiant heat?
Do windowed walls have suitable reflectance values?

Choice of lighting system
Which is most suitable?
Obstacles?

Choice of light source and luminaires
Does the light source meet set requirements for light output, colour rendering, flicker, glare, placement, technical requirements such as service life, ignition and restart, safety, visual and energy requirements, such as motion sensor control?

Maintenance
Has a maintenance plan been prepared?
Accessibility for service and maintenance.

Control system
Can the light be adjusted in relation to daylight?
Adjustable control – individual?
Clear instructions that the user understands?

Coordination with other installations
Such as electrical, HVAC, Water & Sewerage, sprinklers.

Assembly and installation
Are the drawings consistent?
Complete assembly instructions?

Document

Document the set requirements and desires. Does the lighting system meet the requirements?

Monitoring

Can the lighting be measured so that the set requirements can be monitored?

Appendix 12. Example requisition for work glasses

This requisition pertains to an order for a licenced optometrist to perform an eye examination and assess the need for special work glasses (based on Swedish Association of Optometrists' previously prepared requisition).

Company/org.: ______________________ Org. no: ______________________

Name: ______________________ Personal ID no.: ______________________

E-mail: ______________________

Billing information/cost centre: ______________________

Information about the work in question

Preferably photograph the workplace and bring photos along to the examination. The photos should include, for instance, desk/worktable/work equipment, windows, ceiling lighting and, preferably, the employee.

____

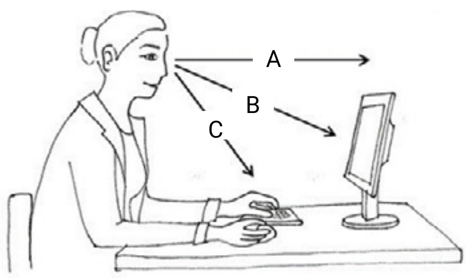
____

____

Fill in for computer work:

Number of screens: 1 ☐ 2 or more ☐

Measure following distances:	Distance (cm)	
A. Room distance:		
B. Screen distance	1:	2:
C: Keyboard:		
D: Other:		



Place and date: Signature of certifying supervisor:

____

Appendix 13. Methods and checklists for investigation and risk assessment of visual working environment in the workplace

Methods/checklists A–J have not been tested for validity or reliability in the formal sense, but experience has shown that these methods work well in practice. Method K, 'VERAM', is validated and reliable (125, 126). Method L 'VERAMlight', is valid in Swedish (submitted paper) and tested in English spring 2025, aiming to have a valid English version in 2026.

	Name	Type Source	Target group and use	Number of questions	Availability Language
A	**Visual ergonomics**	Checklist *The Swedish Work Environment Authority*	Employees for investigation of visual working environment in various types of environments	4	Digital and pdf at av.se *Swedish*
B	**General safety inspection - office**	Checklist *Prevent*	Supervisor and safety representative when performing safety inspection	61	Digital and pdf at prevent.se Free. *Swedish*
C	**General safety inspection - manufacturing**	Checklist *Prevent*	Supervisor and safety representative when performing safety inspection	111	Digital and pdf at prevent.se Free. *Swedish*
D	**Lighting**	Checklist *Prevent*	Supervisor and safety representative as support for in-depth lighting review during safety inspection.	6	Digital and pdf at prevent.se Free. *Swedish*
E	**Computer work**	Checklist *Prevent*	Supervisor and safety representative as support for in-depth review of computer work during safety inspection.	21	Digital and pdf at prevent.se Free. *Swedish*
F	**Simple checklist lighting/visual ergonomics**	Checklist *Prevent*	Non-specialists	17	Digital and pdf at prevent.se Free. *Swedish*
G	**Visual ergonomics questionnaire with visual symptoms index**	*Brief questionnaire about various types of visual symptoms. Originally Swedish National Board of Occupational Safety and Health (Today: The Swedish Work Environment Authority)*	Ergonomists, work environment engineers and other experts. Requires special visual ergonomics expertise. Specially prepared for use at group level as an initial method for assessing whether the visual environment is causing symptoms.	15	Appendix 15 in these guidelines. *English*
H	**Visual screening questionnaire**	Risk factor questionnaire. *Örebro University*	Company nurses, for use in health check-ups or before recommendations to see an optician or eye doctor.	8	Appendix 14 in these guidelines. *English*

	Name	Type Source	Target group and use	Number of questions	Availability Language
I	**Visual ergonomics workplace visits**	Checklist. Includes simple measurement. *Swedish Association of Company Opticians (SFF)*	Ergonomists, work environment engineers and other experts. Requires special visual ergonomics expertise. Prepared to obtain initial picture of the visual environment in a workplace.	10	Appendix 16 in these guidelines. *English*
J	**Detailed lighting/ visual ergonomics checklist**	Checklist for assessing the visual environment. Includes measurements. *Prevent*	Ergonomists, work environment engineers and other experts/specialists	38	Digital at prevent.se Free. *Swedish*
K	**VERAM** (Visual Ergonomics Risk Assessment Method)	In-depth risk assessment method. Visual ergonomics questionnaire and objective risk assessment, including measurements. *Faculty of Engineering – Lund University*	Ergonomists, work environment engineers and other specialists	No info	Available upon confirmation of adequate visual ergonomics training. *Swedish*
L	**VERAM Light**	Risk assessment method – simplified. *Faculty of Engineering – Lund University (Swedish)* *www.veramlight.com (English)*	Ergonomists, work environment engineers and other specialists	21	Available upon confirmation of adequate visual ergonomics training. *Swedish/English* *App available*

Visual ergonomics aspects included/studied in each checklist/method.

	FOR SUPERVISORS, SAFETY REPRESENTATIVES AND SPECIALISTS						FOR SPECIALISTS					
	A	B	C	D	E	F	G	H	I	J	K	L
Name	**Visual ergonomics checklist** *The Swedish Work Environment Authority*	**General safety inspection – Office** *Prevent*	**General safety inspection – Manufacturing** *Prevent*	**Lighting checklist** *Prevent*	**Computer work checklist** *Prevent*	**Simple checklist Lighting/Visual ergonomics** *Prevent*	**Visual ergonomics questionnaire with visual symptoms index** *National Board of Occupational Safety and Health*	**Visual screening questionnaire** *Örebro University*	**Visual ergonomics and workplace visit checklist** *Swedish Association of Company Opticians*	**Detailed Lighting/visual ergonomics checklist** *Prevent*	**VERAM** *Faculty of Engineering – Lund University*	**VERAM light** *Faculty of Engineering – Lund University*
WORKPLACE DESIGN												
Job tasks – different viewing distances	No	No	No	No	Yes	No	No	Partial	Yes	Partial	Task: Partial Dist.: Yes	Task: Partia Dist.: Yes
Work postures neck/eyes shoulders/back	Yes	Partial	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes
Display screen posture – time at screen	Yes	Pos-ture: No Time: Yes	Partial (legi-bility)	No	Yes	Yes	No Partial	Yes	No	Yes	Yes	Pos-ture: Yes Time: No
Reading distance	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
View	Partial	No	Yes	No	No	Yes	No	No	No	Yes	No	No
Light harmony	Yes	No	Yes	No	Yes	No	No	No	No	Partial	Yes	Yes
Visual stress/gaze rest/ recovery	Partial	No	No	No	Partial	No	No	No	No	No	No	No
LIGHT AND LIGHTING												
Daylight	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes
Glare and reflections	Yes	Partial	Partial	Yes	Yes	Yes	No	No	Partial	Yes	Yes	Yes
Lighting measurement	No	No	No	No	No	No	No	No	Partial	Yes	Yes	Yes
Illuminance	Partial	Partial	Yes	Partial	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Luminance	Partial	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Shadows (uneven lighting)	Partial	No	No	No	No	Yes	No	No	No	Yes	Yes	Yes
Type of lighting (also colour temperature, colour rendering and contrasts)	Partial	No	No	No	Yes	Partial	No	No	Yes	Yes	Yes	Yes
Lighting maintenance	Partial	No	Yes	Yes	No	Yes	No	No	No	Yes	No	No
INDIVIDUAL												
Subjective symptoms; visual symptoms, headache, musculoskeletal symptoms	Yes	No	No	No	Yes	No	Yes	Yes	Partial	No	Yes	Yes
Glasses	Yes	Yes	Partial	No	Partial	No	No	Yes	Yes	Yes	Yes	Yes
Known vision problems	Partial	No	No	No	No	No	No	Yes	No	No	No	No
Training	No	No	No	No	Yes	No	No	No	No	No	No	No

Appendix 14. Vision screening questionnaire

The vision screening questionnaire was prepared by Örebro University.

All risk markings must be observed, and should be seen in context in order to consider a recommendation to undergo an eye examination by an optometrist.

Name: ______________________________ Birth year: ______________

Date: ______________________________

Examination performed by: ______________________________

				Risk-factor
General	1.	Age	< 40	> 40
	2.	Vision impairment known from before	No	Yes
	3.	Wears glasses	No	Yes
	4.	Do you work at a terminal more than 4 hours a day?*	No	Yes
	5.	Do you undergo regular eye exams by an optometrist ca. every two years? Pertains mainly to people over 40, or those who have a known vision impairment for which glasses or contact lenses have been tried*.	Yes	No
Distance	6.	Current monocular visual acuity: Right:.......... Left:...........	> 1.0	< 1.0
	7.	Current binocular visual acuity:....................	> 1.0	< 1.0
	8.	With addition of +1.0 monocularly, visual acuity decreases markedly (at least two rows on eye chart). Right:.......... Left:............	Yes	No
Near	9.	Can read 12 pt at 60 cm with current correction	Yes	No
	10.	Can read 8 pt at 33 cm with current correction	Yes	No
Symptom analysis	11.	Do you sometimes have double or blurred vision during close-up work?	No	Yes
	12.	Do you experience burning or irritation in your eyes after reading or doing close-up work?	No	Yes
	13.	Do you sometimes have difficulty maintaining the text in focus when you read for a long time?	No	Yes
	14.	Do you ever have a headache after concentrated close-up work?	No	Yes
	15.	Do you ever get a sense of dizziness or nausea during concentrated close-up work?	No	Yes
	16.	Are you physically active? (i.e. reach a working pulse rate at least 30 minutes a day)*	Yes	No

** Legislated as AFS 2023:11, Ch. 3, Sec. 14*

Appendix 15 a. Calculation and assessment of visual symptoms index

The visual ergonomics questionnaire with visual symptoms scores in appendix 15b is filled out by the relevant employees in the relevant group/in the workplace. **Visual symptoms scores** are first calculated for each individual. The mean value for the group's visual symptoms score provides a **visual symptoms** index for the group. If the visual symptoms index for the group is greater than or equal to three, 3*, then the visual environment is probably having a major impact on the symptoms, and a visual ergonomic risk assessment of the workplace should be performed. If the visual symptoms score for an individual is greater than or equal to three, 3*, it indicates that the individual has a problem that needs to be studied more closely.

Visual symptoms scores

The visual symptoms scores are calculated by multiplying incidence by severity; see example below. Explanation: If the incidence of the symptom 'burning eyes' is 2 (every week) and the severity is 3 (pronounced symptoms), then the score for this symptom equals 6. Once all the symptom scores have been calculated, they are added to produce the visual symptoms score for the individual.

Symptom				**Incidence**				**Severity**		
	YES	**NO**	Occatio-nally	Weekly	Daily		Insignificant	Moderate	Pronounced	
			1	2	3	×	1	2	3	**Points**
Burning eyes	☒	☐	☐	☒	☐		☐	☐	☒	**6**
Itchy eyes	☐	☒	☐	☐	☐		☐	☐	☐	
Gritty feeling	☒	☐	☐	☒	☐		☐	☒	☐	**4**
Eye pain	☐	☒	☐	☐	☐		☐	☐	☐	
Light sensitivity	☒	☐	☐	☐	☐		☒	☐	☐	**1**
Redness	☒	☐	☐	☒	☐		☒	☐	☐	**2**
Teariness	☐	☒	☐	☐	☐		☐	☐	☐	
Dry eyes	☐	☒	☐	☐	☐		☐	☐	☐	
								The total gives the visual symptoms score for the individual:		**13**
Eye fatigue	☐	☒								
Headache	☐	☒								

2 × 3 = 6

Visual symptoms index

The visual symptoms index is the mean value for the visual symptoms scores for the studied group. If a group of five employees has visual symptoms scores of 6, 1, 2, 13 and 2, then the mean value or **visual symptoms index for the group will be 4.8.** The visual symptoms index in this case is more than 3, which indicates that the workplace needs to be investigated further via a visual ergonomic risk assessment, and it is likely that remedial measures will need to be implemented.

** The limit of three was formulated as a suitable limit level by the experts who created the visual ergonomics questionnaire (127) and its associated visual symptoms index.*

Appendix 15 b. Visual ergonomics questionnaire with visual symptoms scores

Name: ______________________ Birth year: ______________

Date: ______________________

Workplace/occupation: ______________________

Contact information: ______________________

Do you have any of the following visual symptoms? If Yes for any symptom, continue to answer with regard to how often it occurs, and its severity.

Symptom			Incidence				Severity			
	YES	NO	Occatio-nally	Weekly	Daily		Insignificant	Moderate	Pronounced	
			1	2	3	×	1	2	3	Points
Burning eyes	☐	☐	☐	☐	☐		☐	☐	☐	
Itchy eyes	☐	☐	☐	☐	☐		☐	☐	☐	
Gritty feeling	☐	☐	☐	☐	☐		☐	☐	☐	
Eye pain	☐	☐	☐	☐	☐		☐	☐	☐	
Light sensitivity	☐	☐	☐	☐	☐		☐	☐	☐	
Redness	☐	☐	☐	☐	☐		☐	☐	☐	
Teariness	☐	☐	☐	☐	☐		☐	☐	☐	
Dry eyes	☐	☐	☐	☐	☐		☐	☐	☐	
								The total gives the visual symptoms score for the individual:		
Eye fatigue	☐	☐								
Headache	☐	☐								

Appendix 16. Visual ergonomics workplace visit checklist

The checklist was originally created for optometrists, and is reproduced here in a somewhat modified version (105).

Date: ______________________________

Year of birth: ______________________________

Type of workplace: ______________________________

Type of work: ______________________________

Visually demanding work (much/some/little): ______________________________

Individual or shared workplace: ______________________________

Display screens (no. and size): ______________________________

	Workplace 1/Screen 1	Workplace 2/Screen 2
Work/viewing distance (cm)		
Gaze angle (from horizontal plane)		
Viewed object (size in mm)		

Subjective examination

Visual symptoms (see visual symptoms index) Yes ☐ No ☐

Eye fatigue Yes ☐ No ☐

Headache Yes ☐ No ☐

Musculoskeletal symptoms? Yes ☐ No ☐

If Yes: When during the day? ______________________________

Localisation? ______________________________

Severity? ______________________________

Incidence? ______________________________

Glasses/contacts? Yes ☐ No ☐

If Yes: Type ______________________________

Perception of the lighting (e.g. glare, insufficient illuminance levels)

____

____

Light measurements

	Job task 1	Job task 2
Illuminance		
Work area		
Display screen (incident)		

	Job task 1	Job task 2
Luminances		
Work area		
Display screen/behind screen		

Remarks/Assessment

Types of light sources

Light direction

Contrasts

Luminance dist.

Glare

Colour temperature

Colour rendering

Flicker

Glare and reflections

Workplace design:

Place for drawing:

Appendix 17. Detailed checklist lighting/visual ergonomics

The checklist is translated from the Swedish version of the checklist published at www.prevent.se

This checklist is primarily for ergonomists/work environment engineers, and other specialists. It can either apply to an operation/premises where several employees work or the conditions for an individual person.

First make the assessment for the operation as a whole and then for individual employees if necessary.

Date: .... Examiner: ....

Company/department/premises:...

Whose workplace (if the assessment applies to an individual employee):

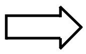
....

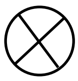
Workplace design

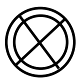
In the box on the right, the workplace can be sketched from above.

a) The work object, e.g. machine, work table, computer

b) The employee's normal position. 

c) Direction of daylight. 

d) Location of ceiling luminaire. 

e) Location of spot luminaire. 

Description of the room/premises (if relevant)

Length........................... m Width:........................... m Ceiling height:........................... m

Colour scheme (glossy/matt, light/dark, sharp/neutral):

Floor:.. .... Walls: ....

Ceiling: ....

Lighting

1. What type of light sources are in the premises?

☐ Fluorescent tubes ☐ Compact fluorescent tubes ☐ Energy-saving lamps
☐ Incandescent lamps ☐ LED ☐ Mercury lamps ☐ High-pressure sodium ☐ Don't know

If LED

2. Does the main lighting consist of recessed LED luminaires?

☐ Yes ☐ No ☐ Don't know

3. If so, are the tiles perceived as dazzling against the ceiling?

☐ Yes ☐ No ☐ Don't know

4. Can they be blocked by recessed frames or other physical shielding?

☐ Yes ☐ No ☐ Don't know

If fluorescent tubes

5. If possible, state the fluorescent tube marking (e.g. 36 W 840) ....

6. Do the luminaires have glow starters? ☐ Yes ☐ No ☐ Don't know

7. Has any fluorescent tube started to flash irregularly? ☐ Yes ☐ No ☐ Don't know

8. Do the ceiling luminaires have

☐ Uplight only? ☐ Downlight only? ☐ Both uplight and downlight?

9. Do the ceiling luminaires have glare shields/louvers/slats? ☐ Yes ☐ No ☐ Don't know

Comment: ....

Light measurements (give approximate average values)

Illuminances

Work area (central field of view): lx

Immediate surroundings (nearby area): lx

Outer surroundings (peripheral field of view): lx

Darkest surface in work area: lx

Uniformity: ..../ .... = ...

(uniformity = darkest surface / average in work area; e.g.180 lx/ 600 lx = 0.3)

Luminances

Work area (central field of view): .... cd/m^2

Immediate surroundings (nearby area): ....cd/m^2

Outer surroundings (peripheral field of view): .... cd/m^2

Floor:...........................cd/m^2 Walls:...........................cd/m^2 Ceiling:...........................cd/m^2

Flicker

10. Is there any indication that any of the light sources emit non-visual flicker? (For example, through experienced discomfort, direct-viewing instruments, mobile phone photos or technical specifications)

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

Daylight

11. Is there satisfactory daylight?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

12. Are there sufficient views?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

13. Is there a way to easily block out bothersome sunlight?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Assessment of lighting conditions

14. Is the direction of the light satisfactory?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

15.Are the contrasts satisfactory?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

16. Is the distribution between light and dark surfaces good (luminance ratios)?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

17. Is any part of the lighting dazzling?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

If Yes, where? ....

18. Are there reflections or glare in the work surfaces?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

If Yes, where? ....

19. Are there disturbing shadows?
☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

If Yes, where? ....

20. Is the lighting too weak?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

If Yes, where? ....

21. Are there sufficient possibilities to regulate the lighting individually?
☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

22. Does the colour rendering of the light sources meet the requirements of the work?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

23. Does the colour scheme work for people with colour vision defects?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

24. Is there disturbing shadowing in common parts of the premises? ☐ Yes ☐ No

If Yes, where? ....

25. Does the illuminance vary greatly between different parts of the premises? ☐ Yes ☐ No

If Yes, where? ....

Maintenance

26. Are there broken light sources? ☐ Yes ☐ No

If Yes, where? ....

27. Are the luminaires noticeably dirty? ☐ Yes ☐ No

If Yes, where? ....

28. Is there flickering or humming noise from the system? ☐ Yes ☐ No

Comment: ....

Assessment of visual requirements and working postures

29. Is the work visually demanding?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment (e.g. is any action required, for whom?): ....

....

30. Are the working positions reasonable?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

31. Does the employee wear progressive glasses or lenses? ☐ Yes ☐ No

Comment (e.g. does it cause problems?): ....

32. Is the need for visual aids met?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

33. Is the need for safety glasses met?

☐ Yes (for all) ☐ Partially (for some) ☐ No (not at all)

Comment: ....

34. What is the overall impression of the visual environment in the premises?

☐ Messy ☐ Harmonious

Comment: ....

Assessment of VDU work (applies to an individual employee)

35. Indicate the employee's direction of gaze in relation to windows:

☐ daylight directly into the eyes, risk of glare

☐ daylight from behind, risk of glare on the screen

☐ daylight from the side, preferred

36. Are there reflections in the screen from light sources or windows? ☐ Yes ☐ No

37. Are the characters on the screen sharp? ☐ Yes ☐ No

38. Are the characters on the screen large enough? ☐ Yes ☐ No

39. Do the characters on the screen have sufficient contrast? ☐ Yes ☐ No

40. Is the direction of gaze slightly downwards when working on a VDU? ☐ Yes ☐ No

41. Does the employee's neck lean back when working on a VDU? ☐ Yes ☐ No

42. Does the colour scheme in the programs used cause any vision problems, e.g. for people with colour vision defects? ☐ Yes ☐ No

Comment: ....

Spontaneous comments from staff about the lighting and visual ergonomics in the workplace

....

....

Other comments:
Need to take action? Need to write an action plan?

....

....

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