TECHNICAL REPORT

ISO/TR 20278

First edition
2015-12-01

Unwanted reflections from the active and inactive areas of display surfaces visible during use

Réflexions non désirées des zones actives et inactives des surfaces de l'écran visibles durant l'utilisation

Reference number
ISO/TR 20278:2015(E)

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Foreword

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The committee responsible for this document is ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

Unwanted reflections from the active and inactive areas of display surfaces visible during use

1 Scope

This Technical Report provides users a summary of the existing knowledge about ergonomics requirements for unwanted reflections on electronic displays. The document furthermore provides some guidance on specification of unwanted reflections.

NOTE ISO 9241 contains normative requirements related to unwanted reflections. It is possible that the information contained in this Technical Report will be used for a future update of ISO 9241.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
asthenopia
weakness or tiring of the eyes accompanied by pain, headache, and dim vision

Note 1 to entry: Symptoms include pain in or around the eyes; headache, usually aggravated by using the eyes for close work; fatigue; vertigo; and reflex symptoms such as nausea, twitching of facial muscles, or migraine.

[SOURCE: Taber's Medical Dictionary]

2.2
disability glare
glare that impairs the vision of objects without necessarily causing discomfort

2.3
direct glare
glare caused by self-luminous objects located in the visual field, especially near the line of sight

2.4
discomfort glare
glare that causes discomfort without necessarily impairing the vision of objects

2.5
glare
condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or by extreme contrasts

2.6
glare by reflection
glare produced by reflections, particularly when the reflected images appear in the same or nearly the same direction as the object viewed

2.7
gloss (of a surface)
mode of appearance by which reflected highlights of light sources of objects are perceived as superimposed on the surface due to the directionally selective properties of that surface

2.8
glossmeter
instrument for measuring the various photometric properties of a surface giving rise to gloss

2.9
reflectometer
instrument for measuring quantities pertaining to reflection

2.10
specular gloss
ratio of the luminous flux reflected from an object in the specular direction for a specified source and receptor angle to the luminous flux reflected from glass with a refractive index of 1,567 in the specular direction

2.11
veiling glare (imaging)
light, reflected from an imaging medium, that has not been modulated by the means used to produce the image

3 Unwanted reflections within the context of the ISO 9241-3xx series

3.1 Glare and unwanted reflections

At various places in the ISO 9241-3xx series, we specifically adopt the CIE definition of glare, which includes both discomfort glare and disability glare. We note that the CIE defines discomfort glare verbally as:

> "glare which causes discomfort without necessarily impairing the vision of objects",[11]

and disability glare as

> "glare that impairs vision".[13]

Glare is commonly classed as direct glare, in which the eye is directly illuminated by some object, such as a display, a luminaire or the sun, and indirect glare, in which the eye is illuminated by light reflected from a surface such as that of a display screen.

3.2 Direct glare in the context of the ISO 9241-3xx standards series

ISO 9241-6 discusses two types of glare in the context of office working environments. Direct glare is described thusly:

> "Direct glare from daylight can typically be caused by a direct view of the sun or clouds and by their reflections on adjacent buildings.",[2]

and

> "Direct glare from artificial lighting can be caused by luminaires or illuminated room surfaces with high luminance".

Clearly, direct glare is seen to be associated with reflections as well as luminance sources directly in the user's line of sight.

In general, room lighting as a source of direct glare has been studied extensively and appropriate designs are well specified. However it is important to note that the recent introduction of new technologies such as luminaires composed of Light Emitting Diodes (LED) has stimulated reconsideration of both the concept of comfortable lighting,[14] and questions about the applicability of existing standards to environments illuminated by LEDs.[14][15] Although we will not discuss direct glare in detail in this paper, the specification of limits for the ambient illuminance for office computer workplaces in standards such as EN 12464-1 overlaps with the discussion of unwanted reflections from the inactive and active areas of displays that are visible during use.

Moreover, there is at least one specification within the ISO 9241-3xx series that deals specifically with the issue of direct glare as defined and discussed by CIE and ISO 9241-6:1999, 3.9, 5.4, Clause 10 and Annex A.

ISO 9241-303:2011, D.5 states a requirement regarding the upper limit for LH, display screen luminance:

> "Glare (disability glare or discomfort glare) shall not be produced by the display". Clearly this refers to a limit on direct glare resulting from an excessively high luminance of a self-luminous object (the display) located in the visual field, especially near the line of sight, exactly satisfying the definition of direct glare.

3.3 Glare by reflection

The second type of glare discussed in ISO 9241-6 is glare by reflection:

> "Glare by reflection can occur in vertical, horizontal and intermediate planes. It can impair visual perception and/or cause discomfort. Disturbing glare caused by reflection on working surfaces and work equipment (for example, visual displays, printed documents, keyboards) should be prevented by suitable design and positioning of the work equipment and the lighting."

The majority of the discussion on glare within the context of the ISO 9241-3xx series pertains to indirect glare resulting from reflections from display surfaces. The context of use for the great majority of the current standards content in the ISO 9241-3xx series is in regard to displays in the office computer workplace, however, this may be expanded in the future to include the home and other environments. It will be critical to maintain distinctions between specifications developed for different environments or contexts of use. It is also important to determine what is meant by the term "disturbing glare", as this term is not defined by the CIE and does not appear to be used outside of Europe.

4 Visual discomfort and glare while using computer displays

4.1 Asthenopia

Visual discomfort while viewing displays is commonly referred to as computer vision syndrome or asthenopia while viewing computer displays. Asthenopia complaints from computer users are common, with estimates of current symptom prevalence ranging as high as 90 % of all computer users.[16] It is an issue well known and documented since the introduction of personal computers.[17]

Sheedy, et al. list potential causes for asthenopia:[18]

> "Direct glare from lighting, anomalies of binocular vision, accommodative dysfunction, uncorrected refractive error, compromised quality of the viewed image, less than optimal viewing angles, flickering visual stimuli such as CRT computer displays, and dry eye".

Sheedy further classifies asthenopic symptoms into two groups, internal and external, based on a principle components analysis of the responses made by subjects during a study of asthenopia. The external symptom factor included eye symptoms such as burning, irritation, and dryness. These symptoms were associated with inducing conditions such as glare, upward gaze angle, flicker, font size, and reduced blink rate.

The internal symptom factor included symptoms such as eyestrain, headache and eye ache, they were associated with inducing conditions such as astigmatism and close viewing distance.

Consequently, while glare is an important causal factor for asthenopia occurring in the office computer workplace, it is important to note that it is one of many causal factors.

5 Unwanted reflections from displays

5.1 General

The question currently before ISO TC 159/SC4 technical committee is that of glare from the inactive areas of the display, such as housings, that are visible during use. It has been proposed that a limit should be set on the reflectivity (specular gloss) of equipment housings visible during use. In order

to more fully understand the issue of glare, this paper first reviews current regulations, technical standards and research findings pertinent to unwanted reflections (glare) from the active and inactive areas of displays.

5.2 Glare and unwanted reflections on screens in the ISO 9241-3xx series

The ISO 9241-3xx series of ergonomic standards addresses the issue of unwanted reflections (glare) on display screens, with regard to the effect on the computer user's comfort and his or her visual performance. The terms "glare" and "unwanted reflections" are used interchangeably within the ISO 9241-3xx series. We will adopt the usage of the term "unwanted reflections" in this paper, with the understanding that it is used to mean both glare and unwanted reflections.

NOTE ISO 9241-305 also uses the term "glare" to refer to a noise source during measurement and unwanted reflections to refer to reflected light interfering with human visual performance.

6 Pertinent regulations regarding glare and unwanted reflections

6.1 European Directive 90-270 — On the minimum safety and health requirements for work with display screen equipment

EU Directive 90-270,[19] which has the force of law for members of the European Union, offers several statements regarding glare and unwanted reflections on screens.

> "The screen shall be free of reflective glare and reflections liable to cause discomfort to the user."
>
> "Possible disturbing glare and reflections on the screen or other equipment shall be prevented by coordinating workplace and workstation layout with the positioning and technical characteristics of the artificial light sources."
>
> "Workstations shall be so designed that sources of light, such as windows and other openings, transparent or translucid walls, and brightly coloured fixtures or walls cause no direct glare and no distracting reflections on the screen."

6.2 The meaning of disturbing glare within the ISO 9241-3xx series

6.2.1 General

Glare by reflection has been defined by the CIE; however, it is not clear what is meant within the context of EU Directive 90-270 by the term "disturbing glare" as it is not defined by the CIE and does not appear to be in common use outside of Europe.

ISO 9241-307 addressed this issue by equating "disturbing glare", as used in EU Directive 90-270, to the CIE definition of glare with the following statement:

> "Disturbing glare thus is a condition of vision in which there is a disturbing degree of visual discomfort or/and a noticeable reduction in the ability to see details or objects."

thus explicitly referencing and adopting the CIE definition of glare:

> "Condition of vision in which there is discomfort or a reduction in the ability to see details of objects, caused by an unsuitable distribution or range of luminance, or too extreme contrasts".

6.2.2 CIE definitions of discomfort glare and disability glare

The CIE[20] defines discomfort glare verbally as

> "glare which causes discomfort without necessarily impairing the vision of objects",

and quantitatively, in the context of direct glare caused by indoor lighting, by means of the Universal Glare Rating (UGR) formula.[12]

The CIE defines disability glare verbally as

> "Disability glare is glare that impairs vision.",[13]

and quantitatively by means of the CIE General Disability Glare Equation.[13] The CIE general formula for discomfort glare caused by indoor lighting is

$$UGR = 8 \log_{10}[(0{,}25/L_B)\sum L^2\omega/\rho^2 \quad (1)$$

where L_B is the background luminance and may be defined as E/π, where E is the indirect illuminance at the eye of the observer and is measured in lux, ω is the solid angle of the glare source, L is the luminance of the source luminaire in the direction of the user's eye, and ρ is the Guth position index.

Although the original Guth position index was described only for the upper half of the visual field, it has been extended by Kim, et. al. over the entire visual field.[21] For the visual angles typical of a computer viewer (about 20° above, below and to the side of the line of sight), it is approximately 1,[21] which is smaller than the value suggested by Luckliesh and Guth,[22] which is about 1,5 for the overlapping regions.

While the CIE discomfort glare rating was developed in the context of direct glare, Howarth and Hodder[23] have examined whether it can be used to estimate the value of a single source luminance that will create an unacceptable reflectance. They note that it required a source luminance many times that which would be expected in the work environment in order to produce a reflection that would have an unacceptable UGR rating.

6.2.3 Unwanted reflections as currently specified and limited in ISO 9241-303, 9241-305 and 9241-307 for the active area of displays (screens)

Currently, ISO 9241-307 specifies maximum acceptable levels of unwanted reflections on the screen (the active area of the display) in terms of contrast ratios, which incorporate diffuse and specular reflection components. It is important to note that both ISO 9241-305 and ISO 9241-303 emphasize the importance of correctly dealing with the haze component.

In ISO 9241-303 we find the following note:

> "Typical LCD (liquid crystal display) monitor screens, for example, comprise only haze components with varying width of the intensity distribution of reflected light; in this case, specular and Lambertian components can be neglected."

ISO 9241-305 emphasizes the necessity to account for any haze component in the determination of the specular component of glare luminance. In the case that

> "…examination of the appearance of the reflected light of the lamp from the position of the LMD showed that the virtual image is distinct but there is substantial luminance reflected beyond the virtual image of the source or no virtual image is observable except for a "fuzzy ball of light", then calculate the small-source specular reflectance, ρ_{small}, while attempting to subtract the diffuse background from the specular component using the luminance factor, ρ_D, obtained from 6.5.6."

It further cautions that this:

"…is an approximate attempt to account for the non-specular reflectance by subtracting it from the specular component. The method specified [in this case] is correct for reflective surfaces for which only a specular and diffuse (Lambertian) component of reflection exists. It does not properly subtract the haze contribution from the reflection. It is a naïve model and can generate confusing results, owing to the assumption by its users that they have the correct specular reflectance and can begin using the form $\mathbf{L = \rho_{small} Ls}$ with impunity."