INTERNATIONAL STANDARD

ISO 9241-333

First edition
2017-04

Ergonomics of human-system interaction —

Part 333:
Stereoscopic displays using glasses

Ergonomie de l'interaction homme-système —

Partie 333: Écrans stéréoscopiques utilisant des lunettes

Reference number
ISO 9241-333:2017(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

A list of all parts in the ISO 9241 series can be found on the ISO website.

Introduction

Recently, due to the improvement of display technologies, users can easily experience stereoscopic displays using glasses, such as TVs with large screen, personal computers, etc. The displays are used not only in the field of leisure, but also in business, education and medical applications.

This document presents the requirements for visual display units (VDUs) with stereoscopic displays using glasses.

ISO 9241-303 covers the display hardware aspect and gives basic requirements for head-mounted displays (HMDs). ISO/TR 9241-331 presents the optical characteristics of autostereoscopic displays. These other documents are closely related to stereoscopic displays using glasses, but are not directly applicable to them, because the need for special glasses or its absence is an important factor in ergonomics. The visual factors of HMDs are also ergonomically different from those of other displays.

This document is not included in the current ISO 9241-300 subseries for 2D displays because stereoscopic displays have unique features. The development of a separate document to cover stereoscopic displays offers better understanding of its unique features. For an overview of the entire ISO 9241 series, see Annex A.

Moreover, IWA 3:2005[19] was published (since withdrawn) to discuss the image contents aspect. This ISO International Workshop Agreement described image safety issues and means of reducing the incidence of undesirable biomedical effects caused by visual image sequences. Visual fatigue caused by stereoscopic images (VFSI) is one of these undesirable effects.

With this document and the related International Standards, the purpose is to develop guidelines for image content where activities are closely related to the use of stereoscopic displays with glasses.

To ensure effective and comfortable viewing, and to reduce VFSI, the standards will need to address both display hardware and the displayed contents. However, as the first step, this document focuses on the display hardware aspect in order to simplify the discussions.

Ergonomics of human-system interaction —

Part 333:
Stereoscopic displays using glasses

1 Scope

This document specifies ergonomic requirements for stereoscopic displays using glasses designed to produce or facilitate binocular parallax. These requirements are stated as performance specifications, aimed at ensuring effective and comfortable viewing conditions for users, and at reducing visual fatigue caused by stereoscopic images on stereoscopic display using glasses. Test methods and metrology, yielding conformance measurements and criteria, are provided for design evaluation. See Annex B for measurement procedures.

This document is applicable to temporally or spatially interlaced types of display. These are implemented by flat-panel displays, projection displays, etc.

Stereoscopic displays using glasses can be applied to many contexts of use. However, this document focuses on business and home leisure applications (i.e. observing moving images, games, etc.). Only dark environments are specified in this document.

For technical explanation of display technologies, see Annex C.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 General terms

3.1.1
stereoscopic display
3D display where depth perception is induced by *binocular parallax* (3.2.1)

[SOURCE: ISO/TR 9241-331:2012, 2.1]

3.1.2
temporally interlaced type
temporally multiplexed type
temporally multiplexed display
temporally multiplexed stereoscopic display
stereoscopic display (3.1.1) that shows each of stereoscopic images sequentially

3.1.3
spatially interlaced type
spatially multiplexed type
spatially multiplexed display
spatially multiplexed stereoscopic display
stereoscopic display (3.1.1) that shows each of stereoscopic images divided in the screen

Note 1 to entry: As a result, each of stereoscopic images is shown simultaneously.

3.1.4
glasses
eye attachment for dividing stereoscopic images into each eye from a *stereoscopic display* (3.1.1) not mounted on the user

3.1.5
active glasses
glasses (3.1.4) where the lenses differently change their optical properties synchronizing with the *stereoscopic display* (3.1.1)

Note 1 to entry: Usually left and right images are displayed alternately on a screen. When a left image is displayed, the left lens of active glasses is turned on to transmit the image and the right lens is turned off to cut off the image.

3.1.6
passive glasses
glasses (3.1.4) where the lenses have differently fixed optical properties

3.1.7
stereoscopic images
set of images with parallax shown on a *stereoscopic display* (3.1.1).

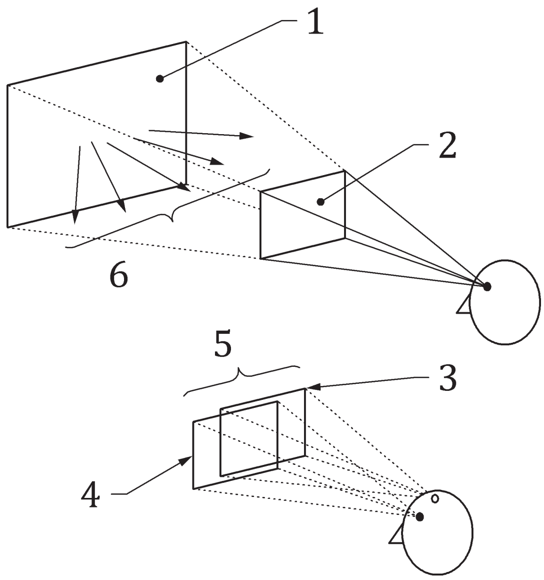
[SOURCE: ISO/TR 9241-331:2012, 2.1.7]

3.1.8
stereoscopic views
pair of sights provided by a *stereoscopic display* (3.1.1), which induce stereopsis

Note 1 to entry: See Figure 1.

Note 2 to entry: Oxford Dictionary defines stereopsis as “the perception of depth produced by the reception in the brain of visual stimuli from both eyes in combination”.

[SOURCE: ISO/TR 9241-331:2012, 2.1.8]



Key

1 autostereoscopic display	4 monocular view (left eye)
2 monocular view (left eye)	5 stereoscopic views
3 monocular view (right eye)	6 stereoscopic images

Figure 1 — Relationship between stereoscopic images, stereoscopic views and monocular view

3.1.9
monocular view
one *stereoscopic view* (3.1.8)

[SOURCE: ISO/TR 9241-331:2012, 2.1.9]

3.2 Human factors

3.2.1
binocular parallax
apparent difference in the direction of a point as seen separately by one eye and the other, while the head remains in a fixed position

Note 1 to entry: Binocular parallax is equivalent to the optic angle between the visual axes of both eyes, when they are fixated to a single point.

[SOURCE: ISO/IWA 3:2005, 2.15 — modified.]

3.2.2
visual fatigue
eyestrain or asthenopia, which shows a wide range of visual symptoms, including tiredness, headache, and soreness of the eyes, caused by watching images in a visual display

Note 1 to entry: See ISO 9241-302:2008, 3.5.3 for the definition of "asthenopia".

[SOURCE: ISO/IWA 3:2005, 2.13 — modified.]

3.3 Performance characteristics

3.3.1
interocular crosstalk
leakage of the *stereoscopic images* (3.1.7) from one eye to the other

Note 1 to entry: In some cases, interocular crosstalk is referred to as "3D crosstalk". In *stereoscopic display* (3.1.1) using *glasses* (3.1.4), the crosstalk means interocular effect and therefore this document uses "interocular" instead of "3D".

3.3.2
interocular luminance difference
difference between the luminance values of the left and right views of a stereoscopic presentation

[SOURCE: ISO 9241-392:2014, 3.16]

3.3.3
pseudoscopic images
pseudostereoscopic images
set of images with inverted parallax shown on a *stereoscopic display* (3.1.1)

4 Display technologies and their guiding principles

For a satisfying human–display interaction, a number of different requirements have to be met at the same time in an appropriate balance. These requirements have been grouped into the following subjects:

— viewing conditions; see 5.1;

— luminance; see 5.2;

— visual artefacts and fidelity; see 5.3.

Each subject includes the related performance characteristics (see Table 1) and the display performance. This document focuses on the significant performance characteristics for stereoscopic display using glasses, which are marked with an asterisk in Table 1. Other performance characteristics, such as "gaze and head tilt angles", "luminance adjustment", etc. are common to the ordinary 2D display, and ISO 9241-303 should be applied.

Table 1 — Performance characteristics by subject

Subject	Performance characteristic
Viewing conditions	Design viewing distance[a]
	Design viewing direction[a]
	Gaze and head tilt angles
Luminance	Illuminance[a]
	Display luminance[a]
	Luminance balance
	Luminance adjustment

[a] This performance characteristic is a focus of this document.

Table 1 *(continued)*

Subject	Performance characteristic
Visual artefacts	Luminance non-uniformity[a]
	Colour non-uniformity
	Contrast uniformity
	Geometric distortions
	Screen and faceplate defects
	Temporal instability (flicker)
	Spatial instability (jitter)
	Moiré effects
	Other instabilities
	Unwanted reflections
	Unwanted depth effects
	Unwanted velocity and acceleration effects
	Interocular luminance difference[a]
	Interocular chromaticity difference
	Interocular contrast difference
	Interocular crosstalk [a]
Fidelity	Colour gamut and reference white
	Gamma and grey scale
	Rendering of moving images
	Image formation time
	Spatial resolution
	Raster modulation or fill factor
	Pixel density
[a] This performance characteristic is a focus of this document.	

5 Ergonomic requirements

5.1 Viewing conditions

5.1.1 General

When viewing the stereoscopic display using glasses, conditions such as design viewing distance, design viewing direction and head rotation (in-plain rotation) angles affect the viewer. In order to achieve a comfortable viewing condition, the design viewing distance and direction need to be determined properly.

NOTE When the viewer rotates his/her head, stereopsis is affected due to the mismatch of displayed parallax. In this case, the effect of the displayed contents is evaluated first, and therefore the detailed requirements are omitted from this document.

5.1.2 Design viewing distance

The design viewing distance is dependent on the application and the display hardware, such as the display area size and the screen resolution. Therefore, the supplier of the display shall specify the design viewing distance. If it is not specified, $1{,}3D_{\mathrm{view}}$ should be applied, where D_{view} is the diagonal of the active display area. Shorter viewing distances can be used in the smaller display (smaller than 9 inches diagonal).

NOTE In stereoscopic displays, the depth sensation is affected by the viewing distance. Many contents for stereoscopic display using glasses assume the viewing distance to be $3H_{\text{view}}$. $3H_{\text{view}}$ is equivalent to $1{,}3D_{\text{view}}$, and $1{,}3D_{\text{view}}$ is better for various aspect ratios of the active display area. When the viewing distance is shorter, the perceived parallax is larger. This condition may increase discomfort and visual fatigue caused by stereoscopic images (VFSI) and therefore needs to be avoided.

5.1.3 Design viewing direction

For general use, the stereoscopic display using glasses should be viewed from any angle of inclination up to at least 40° from the normal to the surface of the display, measured in any plane. For personal use, the display area as a whole should be viewed from at least the design viewing position determined by the design viewing distance and direction. Therefore, the supplier of the display shall specify the design viewing direction, and the specified value shall be applied. If it is not specified, the above requirements should be applied.

5.2 Luminance

5.2.1 General

In order to obtain information from the display, sufficient display luminance is necessary. In addition, a luminous environment to the screen contributes to the display luminance. When the stereoscopic display using glasses is used, the display area and also the environment is viewed through the glasses. Therefore, the display luminance shall be checked through the glasses.

NOTE With the glasses, both the display luminance and the screen illuminance are generally reduced.

5.2.2 Illuminance

The supplier shall specify the design screen illuminance, E_S.

5.2.3 Display luminance

In the ambient illumination for which the display is designed, the display luminance through glasses shall exceed the minimum value for obtaining a sufficient recognizability of the displayed information over the design viewing range and the intended lifetime of the visual display unit.

NOTE In the stereoscopic display using glasses, the display luminance through glasses is checked, because the glasses transmittance affects the display luminance.

5.3 Visual artefacts and fidelity

5.3.1 General

When the display technology is not ideal, the viewer will perceive visual artefacts. In the stereoscopic display using glasses, the visual artefacts are classified into monocular artefacts and binocular artefacts. The monocular artefacts are perceived by one eye and contain screen non-uniformity in luminance, temporal instability (flicker), etc. The binocular artefacts are typical of the stereoscopic display using glasses, and interocular difference in luminance and interocular crosstalk are included.

In this document, the performance characteristics selected are those that are strongly related to stereopsis. Performance characteristics where the current display technology can easily fulfil the requirements (e.g. colour non-uniformity and contrast uniformity) are omitted. For example, the requirements for colour non-uniformity for 2D display are described in ISO 9241-303. However, in some cases the requirements cannot be directly applied to the stereoscopic display using glasses, because the stereoscopic display is viewed through glasses. The effect of glasses should be taken into account.

Moiré effects are also omitted because it is not peculiar to the stereoscopic display using glasses. In the patterned retarder-type display, the moiré phenomenon can sometimes occur. However, this can be evaluated from the luminance non-uniformity. In temporally or spatially interlaced types, interocular chromaticity difference and interocular contrast difference can be omitted because the difference is generally small.

In this document, the temporally instability (flicker) is not applied.

NOTE 1 The display flicker causes discomfort in general and therefore it needs to be avoided. However, in order to establish the requirements, more investigations are necessary. For example, some academic papers have described an asynchronous flicker effect with shutter glasses. If the flicker between both eyes is not synchronized, it is said that the flicker perception can be reduced[6][7].

NOTE 2 See ISO 9241-305: 2008, P15.3 and P15.3A for the measurement method of flicker for 2D displays.

NOTE 3 When a non-inverter type of environmental illumination is observed through the shutter glasses, the viewer sometimes perceives the flicker. In this case, the environmental illumination can be off or darkened. The viewer needs to pay attention to the illumination.

Fidelity is an attribute for indicating the correspondence between displayed images and their original images, and includes colour gamut, reference white, gamma, grey scale, resolution, rendering of moving images, etc. In this document, fidelity is not applied for the same reasons as for visual artefacts.

NOTE 4 ISO 9241-303 suggests that it is uncertain whether images with the highest fidelity will be those preferred by the viewers. The requirements in ISO 9241-303 cannot be directly applied to the stereoscopic display using glasses, because the effect of glasses needs to be considered. For example, the glasses may affect the colour gamut and reference white.

5.3.2 Luminance non-uniformity

For an intended uniform display luminance, the luminance non-uniformity, either step-wise or smooth, in ambient illumination shall not exceed the threshold for reduced visual performance, with a maximum of 1,4:1.

5.3.3 Interocular luminance difference

The luminance differences in the left- and right-eye views should not exceed 25 % and shall not exceed 40 %.

NOTE In the stereoscopic display using glasses, the interocular luminance difference is caused by the glasses influence. For example, in the shutter glasses type, the difference occurs if the shutter timing is not appropriate, because the transmittance between both lenses will be different. Generally, the limit of interocular luminance difference is around 50 %[8][9].

5.3.4 Interocular crosstalk

The interocular crosstalk of each eye should not exceed 5 % and shall not exceed 10 %.

NOTE 1 Interocular crosstalk is the leakage of the stereoscopic images from one eye to the other. When interocular crosstalk occurs a double image can be viewed. It is generally said that 1 % to 2 % crosstalk can be perceived, and therefore the perception limit is around 2 %[10]. When crosstalk increases, stereopsis is disturbed, and then it causes discomfort and VFSI. Generally, the tolerance limit is around 10 %[11] and less than 5 % is recommended[12]. Using the current display technology, in the perpendicular direction the stereoscopic display has lower crosstalk but angular dependence exists. Therefore, the interocular crosstalk is checked across the design viewing angles.

NOTE 2 The displayed contents are strongly related to the perception of interocular crosstalk. Generally, white-and-black interocular crosstalk is used, because its influence is large. However, many kinds of grey level crosstalk measurement are recently proposed[13][14][15][16][17][18]. When the measurement is applied, the relation between the grey level crosstalk level and its influence is evaluated.