INTERNATIONAL STANDARD

ISO 9241-392

First edition
2015-05-15

Ergonomics of human-system interaction —

Part 392: Ergonomic recommendations for the reduction of visual fatigue from stereoscopic images

Ergonomie de l'interaction homme-système —
Partie 392: Exigences ergonomiques pour diminuer la fatigue visuelle induite par des images stéréoscopiques

Reference number
ISO 9241-392:2015(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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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary Information.

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

ISO 9241 consists of the following parts, under the general title *Ergonomic requirements for office work with visual display terminals (VDTs)*:

— *Part 1: General introduction*

— *Part 2: Guidance on task requirements*

— *Part 5: Workstation layout and postural requirements*

— *Part 6: Guidance on the work environment*

— *Part 11: Guidance on usability*

— *Part 12: Presentation of information*

— *Part 13: User guidance*

— *Part 14: Menu dialogues*

— *Part 15: Command dialogues*

— *Part 16: Direct manipulation dialogues*

ISO 9241 also consists of the following parts, under the general title *Ergonomics of human-system interaction*:

— *Part 20: Accessibility guidelines for information/communication technology (ICT) equipment and services*

— *Part 110: Dialogue principles*

— *Part 129: Guidance on software individualization*

— *Part 143: Forms*

— *Part 151: Guidance on World Wide Web user interfaces*

— *Part 154: Interactive voice response (IVR) applications*

— *Part 171: Guidance on software accessibility*

— *Part 210: Human-centred design for interactive systems*

— *Part 300: Introduction to electronic visual display requirements*

— *Part 302: Terminology for electronic visual displays*

— *Part 303: Requirements for electronic visual displays*

— *Part 304: User performance test methods for electronic visual displays*

— *Part 305: Optical laboratory test methods for electronic visual displays*

— *Part 306: Field assessment methods for electronic visual displays*

— *Part 307: Analysis and compliance test methods for electronic visual displays*

— *Part 308: Surface-conduction electron-emitter displays (SED)*

— *Part 309: Organic light-emitting diode (OLED) displays*

— *Part 310: Visibility, aesthetics and ergonomics of pixel defects*

— *Part 331: Optical characteristics of autostereoscopic displays*

— *Part 400: Principles and requirements for physical input devices*

— *Part 410: Design criteria for physical input devices*

— *Part 420: Selection of physical input devices*

— *Part 910: Framework for tactile and haptic interaction*

— *Part 920: Guidance on tactile and haptic interactions*

For the other parts under preparation, see Annex A.

Introduction

When a person views a three-dimensional object, the lateral distance between the eyes provides each with a slightly different retinal image. The fusion of these retinal images by the brain provides a single percept with an associated sense of depth termed as stereopsis. Recent advances in the imaging technology have created a notable increase in our chances of viewing artificially-created stereoscopic images. The technology creates two different images, one of which is seen by one eye and the other by the other eye. Their fusion results in the sensation of stereopsis.

Stereoscopic images are appealing because of their heightened sense of reality compared with the traditional 2D images. Presentations of stereoscopic images also provide clear depth information and, for this reason, the broad use of stereoscopic images is anticipated in fields such as medicine and industry. However, there are scientific data indicating that without careful consideration of the properties of the human visual system, the stereoscopic presentation of images might induce undesirable effects.

This part of ISO 9241 describes the basic and minimal conditions for comfortable viewing of stereoscopic images. It is intended to promote an environment in which viewers can enjoy the benefits of stereoscopic images without adverse effects. In such an environment, new technologies for stereoscopic images can also be actively developed and applied in various fields. This part of ISO 9241 is not intended to restrict the freedom of expression or artistic creativity in the image culture.

This part of ISO 9241 is based on scientific findings related to the possible undesirable effects of viewing stereoscopic images and in the future, this part of ISO 9241 can be revised as new scientific data.

This part of ISO 9241 specifies human-system interaction standards. Readers who need guidance on other aspects of human–system interaction can therefore refer to other documents in ISO 9241 (see Annex A for an overview of the entire ISO 9241 series).

Ergonomics of human-system interaction —

Part 392:
Ergonomic recommendations for the reduction of visual fatigue from stereoscopic images

1 Scope

This part of ISO 9241 establishes recommendations for reducing the potential visual discomfort and visual fatigue experienced during viewing of stereoscopic images under defined viewing conditions. Visual fatigue and discomfort might be produced by the stereoscopic optical stimulus of disparate images that were presented binocularly.

This part of ISO 9241 is also applicable to the final products of stereoscopic presentations which depend on stereoscopic image content and stereoscopic displays when viewed under appropriate defined conditions. Therefore, the recommendations are intended for people responsible for the design, development, and supply of stereoscopic image content as well as stereoscopic displays.

NOTE 1 See Annex B for appropriate viewing conditions.

The recommendations in this part of ISO 9241 are applicable to stereoscopic displays such as those with glasses and two-view autostereoscopic displays, stereoscopic head-mounted displays, and stereoscopic projectors. Moreover, they are applicable to stereoscopic image content intended to be presented on the above-mentioned stereoscopic displays and stereoscopic presentations that are realized by the combinations of these images and displays.

NOTE 2 Annex C presents numerical criteria as an informative reference.

NOTE 3 Other guidance might need to be established by referring to this part of ISO 9241 when requirements and recommendations specific to each type of stereoscopic image content or stereoscopic display become necessary.

NOTE 4 ITU generally sets the standards for broadcasting.

NOTE 5 ISO 9241-303:2011, Annex E provides guidelines for virtual displays which are intended for stereoscopic head-mounted displays.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9241-303, *Ergonomics of human-system interaction — Part 303: Requirements for electronic visual displays*

3 Terms and definitions

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

3.1
stereopsis
binocular, visual perception of depth or three-dimensional space

Note 1 to entry: See ISO 9241-302:2008, 3.3.40.

3.2
binocular parallax
apparent difference in the position of an object as seen separately by one eye and by the other while the head remains in a fixed position

Note 1 to entry: See ISO/TR 9241-331:2012, 2.2.1.

Note 2 to entry: Extent of binocular parallax of a point is equivalent to the optic angle between the visual axes of both eyes when they are fixated on the point.

3.3
horizontal disparity
difference in the relative position of visual images of an object on the two retinas

Note 1 to entry: See ISO 9241-302:2008, 3.5.26.

3.4
vergence angle
angle between the visual axes of the left and right eyes

Note 1 to entry: See ISO 9241-302:2008, 3.5.55.

3.5
accommodation
adjustment of the optics of an eye to keep an object in focus on the retina as its distance from the eye varies

Note 1 to entry: Accommodation can also be a process of adjusting the focal length of a lens.

Note 2 to entry: Accommodation can also refer to an increase in the power of a lens of an eye.

Note 3 to entry: See ISO 9241-302:2008, 3.5.1.

3.6
visual global motion
wide spatial range of visual motion composed of different velocities and directions that are systematically aligned in a moving image

Note 1 to entry: There are generally six types of visual global motion that correspond to the different types of motion of a camera during the shooting of images which are rotation around and translation along the pitch, yaw, and roll axes.

3.7
stereoscopic display
display device or system that makes depth perception possible as a result of *binocular parallax* (3.2)

Note 1 to entry: People perceive depth owing to the retinal disparity produced by binocular parallax.

3.8
stereoscopic image content
set of image information that results in *stereoscopic images* (3.9) when shown on a *stereoscopic display* (3.7)

3.9
stereoscopic images
set of images presented on a stereoscopic display

3.10
stereoscopic presentation
presentation of stereoscopic images on a stereoscopic display

3.11
stereoscopic view
single sight produced as a consequence of fusion of left and right views of a *stereoscopic presentation* (3.10) which induces *stereopsis* (3.1)

3.12
interocular vertical misalignment
difference between vertical positions of the left and right views of a stereoscopic presentation

3.13
interocular rotational misalignment
difference between rotational positions of the left and right views of a stereoscopic presentation

3.14
interocular magnification difference
difference between apparent size of the left and right views of a stereoscopic presentation

3.15
interocular geometrical difference
geometrical misalignment of the left and right views of a stereoscopic presentation including *interocular vertical misalignment* (3.12), *interocular rotational misalignment* (3.13), and *interocular magnification difference* (3.14)

3.16
interocular luminance difference
difference between the luminance values of the left and right views of a stereoscopic presentation

3.17
interocular contrast difference
difference between the luminance contrast values of the left and right views of a stereoscopic presentation

3.18
interocular chromaticity difference

difference between the chromaticity values of the left and right views of a stereoscopic presentation

3.19
interocular photometric difference
photometric mismatch between the left and right views of a stereoscopic presentation including *interocular luminance difference* (3.16), *interocular contrast difference* (3.17), and *interocular chromaticity difference* (3.18)

3.20
accommodation-convergence mismatch
difference in distance information indicated by *accommodation* (3.5) and convergence stimuli of an object

Note 1 to entry: Accommodation-convergence mismatch can be produced when stereoscopic images are presented on a depth plane (e.g. stereoscopic display surface) which is well nearer or further from the viewers than where the images are simulated.

3.21
design viewing distance
distance or range of distances between the viewers' eyes and the screen of a stereoscopic display that is designed for stereoscopic presentation

Note 1 to entry: Design viewing distance can be specified for both *stereoscopic image content* (3.8), stereoscopic displays, and stereoscopic presentation.

4 Guiding concepts

4.1 Framework

To reduce the potential visual discomfort and visual fatigue experienced during viewing of stereoscopic images, the recommendations in this part of ISO 9241 are established based on the review of the factors (see 4.2) that are considered in terms of the stereoscopic optical stimulus of disparate images

presented binocularly. Therefore, other standards specific to each type of stereoscopic image content or stereoscopic display could be established by referring to this part of ISO 9241.

4.2 Review of factors

4.2.1 General

This part of ISO 9241 focuses on the major factors that have the potential to induce visual discomfort and visual fatigue during viewing of stereoscopic images. These factors, listed below, have been empirically determined and are widely recognized in the scientific literature. Since these factors are affected by the viewing conditions, such as the viewing distance, the viewing conditions should also be specified.

1) Interocular geometrical differences: Interocular vertical misalignment, interocular rotational misalignment, and interocular magnification difference.

2) Interocular photometric differences: Interocular luminance difference, interocular contrast difference, and interocular chromaticity difference.

3) Accommodation-convergence mismatch.

4) Other factors to be considered for stereoscopic presentation: Interocular temporal asynchrony, visual motion-induced motion sickness, and vergence limits.

In establishing guidance, the above-mentioned factors must be considered in light of their level of importance by reviewing the four items listed below.

a) Efficacy of factor: The probability that a factor will cause visual discomfort or visual fatigue in the viewers of stereoscopic images.

b) Inevitability of factor: The extent to which the effect of a factor can be reduced especially when the origin of the factor might be related to the principle of stereoscopic presentation.

c) Accumulation of scientific knowledge: Whether a sufficient amount of scientific data which determine the relation between each of the factors and visual fatigue, and/or discomfort, have been collected as well as their practical applicability to ergonomic guidance.

d) Availability of measurement methods: Whether measurement methods are readily available for assessing products.

In the following subsections, the major factors listed above (items 1 to 4) are reviewed in terms of items A to D.

4.2.2 Interocular geometric differences

4.2.2.1 General

Interocular geometric differences refer to the geometrical misalignment of the left and right views of a stereoscopic presentation such as interocular vertical misalignment, interocular rotational misalignment, and interocular magnification difference which are generally thought to induce visual fatigue and discomfort. The geometrical misalignment of the left and right views of a stereoscopic presentation is determined by the interaction between such differences in stereoscopic images and stereoscopic displays.

4.2.2.2 Efficacy of factor

Even a relatively small interocular geometrical difference can easily induce discomfort and make binocular fusion difficult.

4.2.2.3 Inevitability of factor

Interocular geometric differences can be caused by misalignment of the left and right cameras in the shooting of stereoscopic images and/or by misalignment of the left and right displayed images of a stereoscopic display that does not present those images within the same spatial frame. The differences can be reduced to some extent by making adjustments during the editing of images by adjusting devices and by carefully setting the viewing conditions.

4.2.2.4 Accumulation of scientific knowledge

Although there are no scientific data about the condition of the stereoscopic image size generally used at home, fundamental data have been collected which determine the relation between each of the factors and discomfort (e.g. see References [13] and [19]) and can serve as useful references.

4.2.2.5 Availability of measurement methods

Depending on necessity and feasibility, measurements can be taken separately for stereoscopic image content and stereoscopic displays or for final products of stereoscopic presentations. Firstly, measurements of stereoscopic image content can be performed by geometrical analysis by which the factors of interocular vertical misalignment, interocular rotational misalignment, and interocular magnification difference can be extracted separately as the factor of optical distortion caused by lens aberration (e.g. Hartly and Zisserman, 2004). Secondly, measurements of stereoscopic displays can be performed using generally available optical measurement devices.[30] Thirdly, measurements of stereoscopic presentations can be performed by combining the optical measurements of a whole stereoscopic image and geometrical analysis of the image.

4.2.3 Interocular photometric differences

4.2.3.1 General

Interocular photometric differences refer to the photometric mismatch between the left and right views of a stereoscopic presentation such as the interocular luminance difference, interocular contrast difference, and interocular chromaticity difference which are generally thought to induce visual fatigue and discomfort. Photometric mismatch between the left and right views of a stereoscopic presentation is determined by the interaction between such differences in stereoscopic images and in stereoscopic displays.

4.2.3.2 Efficacy of factor

Interocular photometric differences might induce discomfort when present to a relatively large degree (e.g. see References [2] and [11]).

4.2.3.3 Inevitability of factor

An interocular photometric difference can be caused by a photometric difference between the left and right cameras during the shooting of stereoscopic images and/or by a photometric difference between the left and right displayed images of a stereoscopic display. The difference can be reduced to some extent by making adjustments during the editing of images and by adjusting the devices. Since luminance, contrast, and chromaticity in a stereoscopic presentation are, in general, mutually related, they generally cannot be manipulated independently.

4.2.3.4 Accumulation of scientific knowledge

There are few scientific data determining the relation between interocular photometric difference and discomfort (e.g. see References [2] and [11]). A number of conditions can be considered as major contributory factors such as the display size, the surrounding lighting conditions, and the duration and frequency of the presentation of the factors.

4.2.3.5 Availability of measurement methods

Depending on necessity and feasibility, measurement can be taken separately for stereoscopic image content and stereoscopic displays, or for final products of stereoscopic presentations. Firstly, measurements of stereoscopic image content can be performed by comparing the photometric results obtained for corresponding points in the left and right image content. Secondly, measurements of stereoscopic displays can be performed using generally available optical measurement devices, whereas the measurements usually differ depending on the type of stereoscopic display. Thirdly, the measurement of stereoscopic presentations can be performed by combining the optical measurements of a whole stereoscopic image and comparing the photometric results obtained for the corresponding points in the left and right images.

4.2.4 Interocular photometric interaction

4.2.4.1 General

Interocular photometric interaction refers to unwanted photometric interaction, such as crosstalk, which affects the view in one eye through information about the image in the other eye.

4.2.4.2 Efficacy of factor

Crosstalk is recognized as "a primary factor affecting the image quality" of stereoscopic image presentation[24] and might induce discomfort (e.g. see References [11] and [26]).

4.2.4.3 Inevitability of factor

Crosstalk can occur in the capture, transmission, storage, editing, display, and separation stages, but most of the literature focuses on the display and separation stages[24] which can be the major stages of crosstalk occurrence. Crosstalk can be reduced to some extent by adjusting the devices.

4.2.4.4 Accumulation of scientific knowledge

Although crosstalk in stereoscopic image presentation has been widely studied (e.g. Reference [24] for review and References [11], [25], [26], [27], and [28]), the literature does not necessarily contain reports about the effects on visual fatigue and discomfort. Moreover, the numerical range of quantitative characteristics varies widely more than tenfold among the literature and sometimes experimental conditions relating to visual images, devices, and so forth, are not clear. The conditions of binocular disparity and contrast can be considered major contributory factors[28]. For quantifying crosstalk, several methods have been proposed. However, they are not necessarily perceptually relevant. Finally, crosstalk is quantified by using various equations which might sometimes lead to miscommunications.

4.2.4.5 Availability of measurement methods

Optical measurement devices can be used to measure crosstalk. In fact, measurement methods have been reported to use various optical devices.[24] However, the measurement methods differ by type of stereoscopic display (see ISO/TR 9241-331). The measurement methods using grayscale charts have yet to be established for stereoscopic displays in which the crosstalk process is highly non-linear.

4.2.5 Accommodation-convergence mismatch

4.2.5.1 General

In stereoscopic presentations, when visual targets are simulated as being in front of or behind the stereoscopic display surface, there can be a difference between the distance information of accommodation and convergence. The factor of accommodation-convergence mismatch, thus, refers to a mismatch between the accommodation and convergence stimuli and can possibly induce visual discomfort.

4.2.5.2 Efficacy of factor

Discomfort associated with a large extent of simulated depth has been well established empirically and has also been observed experimentally (e.g. see References [4], [5], [17], and [22]). Although there are large individual differences in the effect of accommodation-convergence mismatch on discomfort, the obtained results are basically consistent among the literature.

4.2.5.3 Inevitability of factor

Stereoscopic displays included in the scope of this part of ISO 9241 in principle include this factor for stereoscopic presentation. There are insensitive regions of accommodation and convergence that appear as depth of focus and fixation disparity respectively. Therefore, the effect of this factor can be reduced to some extent by reducing the simulated depth of visual objects from the stereoscopic display surface.

4.2.5.4 Accumulation of scientific knowledge

Various experimental data have been reported for accommodation-convergence mismatch (e.g. see References [1], [13], [15], and [21]). However, a number of conditions remain to be explored further such as the spatial distribution of simulated depth (especially in relation to edge violation), temporal variation, size, and duration of presented images.

4.2.5.5 Availability of measurement methods

The measurements are performed basically for both stereoscopic displays and stereoscopic image content. The relative disparity in stereoscopic displays and that of stereoscopic image content in terms of the display surface can be evaluated through optical measurements and/or geometrical analysis of image content.

4.2.6 Other factors to be considered for stereoscopic presentation

4.2.6.1 General

There are other factors to be considered as well such as interocular temporal asynchrony, visual motion-induced motion sickness, and vergence limits. These factors are respectively defined as follows: (i) the temporal difference of corresponding left and right images presented stereoscopically; (ii) visual global motion and other spatially wide ranges of motion that could induce motion sickness; (iii) the limits of vergence which is the point at which the visual axes of the two eyes diverge beyond the point of being parallel.

4.2.6.2 Interocular temporal asynchrony

4.2.6.2.1 Efficacy of factor

Interocular temporal asynchrony possibly raises multiple other factors such as interocular geometrical and photometric differences.

4.2.6.2.2 Inevitability of factor

Interocular temporal asynchrony can be induced when the left and right images of stereoscopic presentation are not optimally synchronized. This asynchrony can occur in the capture, transmission, storage, editing, display, and separation stages. It can also be reduced to some extent by adjusting the devices.

4.2.6.2.3 Accumulation of scientific knowledge

Basic experiments have been reported for interocular temporal asynchrony and visual motion-induced motion sickness.