International Standard

ISO 9241-820

First edition
2024-04

# Ergonomics of human-system interaction —

## Part 820: Ergonomic guidance on interactions in immersive environments, including augmented reality and virtual reality

*Ergonomie de l'interaction homme-système —*

*Partie 820: Lignes directrices ergonomiques relatives aux interactions en environnements immersifs, y compris la réalité augmentée et la réalité virtuelle*



Reference number
ISO 9241-820:2024(en)



ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

# Contents

Page

# Foreword

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

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

The use of immersive environments is rapidly spreading beyond the fields of research and gaming into many other application areas. Given the human-system issues unique to systems with these characteristics, timely guidance covering these issues is necessary to help all sectors of industry to design, field and operate quality immersive systems and build appropriate trust in products and services that use these systems.

This document provides ergonomics guidance for a range of immersive environments, including those involving virtual reality, mixed reality and augmented reality. This guidance builds on the more general guidance in the ISO 9241 series, which applies to interactive tools and the physical environment within which they are used.

# Ergonomics of human-system interaction —

# Part 820:
# Ergonomic guidance on interactions in immersive environments, including augmented reality and virtual reality



## 1 Scope

This document identifies ergonomic or human-systems issues and guidance for the development and use of systems involving immersive environments, augmented reality and virtual reality. This includes:

a) environments where the user is provided with a perception of being physically present in a virtually-created world;

b) environments where the user is represented virtually and can interact in a real-world environment;

c) environments involving artificial reality, augmented reality, virtual reality, mixed reality and similar simulated realities;

d) computer-generated environments where the user interacts with simulated objects in a manner similar to how the user would interact with the real-world counterparts of these objects.

This document is not an exploration of the philosophical, ethical or political issues surrounding the use of immersive environments.

This document limits its treatment of the technologies used to create immersive environments to focusing on their interactions with users and does not investigate other aspects of these technologies.

The target audience for this document is decision-makers, designers and engineers who would benefit from the consideration of human-systems issues of immersive environments. Futurists, researchers, technology developers, regulators and legislators could also find this document useful.

## 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 terminology databases for use in standardization at the following addresses:

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

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

### 3.1 High-level concepts

**3.1.1**
**immersion**
<immersive environments> experience and participation in a particular *environment* (3.2.5)

**3.1.2**
**presence**
<immersive environments> psychological sense of being in a particular *environment* (3.2.5)

**3.1.3**
**flow**
<immersive environments> state of mind an individual enters when completely involved or focused on any challenging and/or enjoyable activity

**3.1.4**
**naturalness**
correspondence with everyday interactions between humans and real-world objects that they interact with

Note 1 to entry: Naturalness relates to everyday behaviours that can be expected to be performed without any specialized learning or training.

[SOURCE: ISO/IEC 4944:—,[1)] 3.1.4, modified — "expected to have already learned" has been replaced by "expected to be performed without any specialized learning or training" in Note 1 to entry, and the EXAMPLE has been removed.]

## 3.2 Realities and environments

**3.2.1**
**reality**
<immersive environments> set of facts, beliefs and rules that are accepted as true

**3.2.2**
**natural world**
<immersive environments> world that has actual physical existence

Note 1 to entry: In this document, "natural world" is used to refer to the physical elements of the *real world* (3.2.3).

**3.2.3**
**real world**
<immersive environments> *natural world* (3.2.2) as experienced by the *user* (3.4.1)

Note 1 to entry: The real world goes beyond the physical existence of the natural world to also include the facts, opinions and knowledge about, and the actions and experiences of and with, the components of the natural world that are common to most people in the user's society.

Note 2 to entry: The real world represents the perception that individuals have of the natural world. Thus, there can be minor differences between different individuals' perceptions of what the real world is, despite all of these being based on their experiences within the same natural world.

Note 3 to entry: In this document, the term "real world" is used to contrast with artificially-created *immersive environments* (3.2.6).

**3.2.4**
**alternative reality**
<immersive environments> possible perceivable *reality* (3.2.1)

**3.2.5**
**environment**
<immersive environments> physical, chemical, biological, organizational, social and cultural factors surrounding one or more persons

[SOURCE: ISO 26800:2011, 2.3, modified — "<immersive environments>" has been added as the domain.]

1) Under preparation. Stage at the time of publication: ISO/IEC DIS 4944:2024.

**3.2.6**
**immersive environment**
*environment* (3.2.5) that surrounds a *user* (3.4.1) and with which the user interacts

Note 1 to entry: For the purposes of this document, immersive environments are those environments that involve virtual, mixed or augmented realities.

**3.2.7**
**virtual reality**
interactive experience taking place within a simulated *environment* (3.2.5)

**3.2.8**
**mixed reality**
merging of the *real world* (3.2.3) and virtual worlds to generate new *environments* (3.2.5) where physical and synthetic objects co-exist and interact

[SOURCE: ISO/IEC 18038:2020, 3.14, modified — The admitted term "MR" has been removed.]

**3.2.9**
**augmented reality**
interactive experience of a *real-world* (3.2.3) *environment* (3.2.5) whereby the objects that reside in the *real world* (3.2.3) are augmented by computer-generated perceptual information

[SOURCE: ISO/IEC 18038:2020, 3.2, modified — The admitted term "AR" has been removed.]

## 3.3 Systems and interfaces

**3.3.1**
**augmented reality system**
view of the physical world that is supplemented by computer-generated text, images, data or other media

[SOURCE: ISO/IEC/IEEE 26511:2018, 3.1.4]

**3.3.2**
**mixed reality system**
**mixed and augmented reality system**
system that uses a mixture of representations of physical world data and virtual world data as its presentation medium

[SOURCE: ISO/IEC 18039:2019, 3.1.13]

**3.3.3**
**user interface**
**UI**
set of all the components of an interactive system that provide information and controls for the *user* (3.4.1) to accomplish specific tasks with the interactive system

[SOURCE: ISO 9241-110:2020, 3.10]

**3.3.4**
**natural user interface**
**NUI**
*user interface* (3.3.3) where the *user* (3.4,1) operates the interface through an intuitive manner related to everyday human behaviours in a *real world* (3.2.3)

Note 1 to entry: "Natural" refers to the user's expectations, behaviour and feelings that are involved in interacting with an NUI.

Note 2 to entry: Everyday human behaviours refer to actions of the user which can be performed without the need for learning and training beforehand.

Note 3 to entry: Interactions with NUIs typically model interactions performed in the *natural world* (3.2.2), including (but not limited to) touch, gestures and/or auditory interactions.

[SOURCE: ISO/IEC 4944:—, 3.1.2, modified — "through a manner" has been replaced by "through an intuitive manner" in the definition; "behaviours that the user can been expected to have already learned" has been replaced by "actions of the user which can be performed without the need for learning and training beforehand" in Note 2 to entry; "vocal interactions" has been replaced by "auditory interactions" in Note 3 to entry.]

## 3.4 Ergonomic-related concepts

**3.4.1**
**user**
person who interacts with a system, product or service

Note 1 to entry: Users of a system, product or service include people who operate the system, people who make use of the output of the system and people who support the system (including providing maintenance and training).

[SOURCE: ISO 9241-11:2018, 3.1.7]

**3.4.2**
**guiding user**
*user* (3.4.1) who exerts some level of control over the situation experienced by other users within an *immersive environment* (3.2.6)

EXAMPLE 1 An administrator, who is outside the immersive environment, monitors what is happening in the immersive environment and can make real-time changes to it that will have an immediate effect on users within the immersive environment.

EXAMPLE 2 Within an immersive environment used for training teams, a team leader instructs other members of the team on what they are to do individually.

**3.4.3**
**usability**
extent to which a system, product or service can be used by specified *users* (3.4.1) to achieve specified goals with effectiveness, efficiency and satisfaction in a specified *context of use* (3.4.8)

Note 1 to entry: The "specified" users, goals and context of use refer to the particular combination of users, goals and context of use for which usability is being considered.

Note 2 to entry: The word "usability" is also used as a qualifier to refer to the design knowledge, competencies, activities and design attributes that contribute to usability, such as usability expertise, usability professional, usability engineering, usability method, usability evaluation and usability heuristic.

[SOURCE: ISO 9241-11:2018, 3.1.1]

**3.4.4**
**accessibility**
extent to which products, systems, services, *environments* (3.2.5) and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified *contexts of use* (3.4.8)

Note 1 to entry: Context of use includes direct use or use supported by assistive technologies.

[SOURCE: ISO 9241-112:2017, 3.15]

**3.4.5**
**user experience**
*user* (3.4.1) perceptions and responses that result from the use and/or anticipated use of a system, product or service

Note 1 to entry: Users' perceptions and responses include users' emotions, beliefs, preferences, perceptions, comfort, behaviours and accomplishments that occur before, during and after use.

Note 2 to entry: User experience is a consequence of brand image, presentation, functionality, system performance, interactive behaviour and assistive capabilities of a system, product or service. It also results from the user's internal and physical state resulting from prior experiences, attitudes, skills, abilities and personality, and from the *context of use* (3.4.8).

[SOURCE: ISO 9241-11:2018, 3.2.3, modified — Notes 3 and 4 to entry have been removed.]

**3.4.6**
**harm from use**
negative consequences regarding health, safety, finances or the *environment* (3.2.5) that result from use of the system

Note 1 to entry: The negative consequences can be for the user or for any other stakeholder.

Note 2 to entry: Although avoidance of harm from use (i.e. eliminating any exposure of risk that poses potential harm) cannot be achieved completely, the design of an interactive system can aim to mitigate risks to an acceptable minimum.

[SOURCE: ISO 9241-11:2018, 3.2.4, modified — Note 2 to entry added.]

**3.4.7**
**human-centred quality**
extent to which requirements for *usability* (3.4.3), *accessibility* (3.4.4), *user experience* (3.4.5) and avoidance of *harm from use* (3.4.6) are met

Note 1 to entry: Provision of the necessary technical functionality is a prerequisite for human-centred quality.

Note 2 to entry: Usability, accessibility, user experience and avoidance of harm from use can only be managed to the extent that they can be controlled by designed aspects of the interactive system.

Note 3 to entry: Human-centred quality is a collective term for the intended outcomes of interaction of the user with the system.

[SOURCE: ISO 9241-11:2018, 3.2.1]

**3.4.8**
**context of use**
combination of users, goals and tasks, resources and *environment* (3.2.5)

Note 1 to entry: The "environment" in a context of use includes technical, physical, social, cultural and organizational environments.

[SOURCE: ISO 9241-11:2018, 3.1.15]

## 3.5 Interaction-related concepts

**3.5.1**
**natural user interface interaction**
**NUI interaction**
user-system interaction making use of a *natural user interface* (3.3.4)

**3.5.2**
**modality**
mode of interaction referring to one of the human senses

[SOURCE: ISO 9241-112:2017, 3.11, modified — Notes to entry have been removed.]

**3.5.3**
**multi-modal**
mode of interaction simultaneously involving multiple modes of sensing

Note 1 to entry: This usually involves the visual, auditory and *haptic* (3.5.4) *modalities* (3.5.2).

**3.5.4**
**haptics**
sensory and/or motor activity based in the skin, muscles, joints and tendons

Note 1 to entry: Haptics consists of two parts: *touch* (3.5.5) and kinaesthesis.

[SOURCE: ISO 9241-910:2011, 2.1]

**3.5.5**
**touch**
sense based on receptors in the skin

Note 1 to entry: Cutaneous receptors are used for the perception of touch.

[SOURCE: ISO 9241-910:2011, 2.3]

# 4 Unique characteristics of immersive environments

## 4.1 General

This clause identifies some of the unique characteristics of immersive environments that go beyond those involved in other types of interactive systems. While these unique characteristics give rise to ergonomic issues, this clause only identifies the characteristics and leaves the ergonomic issues to Clauses 5-9.

## 4.2 Realities

### 4.2.1 General

Computers provide the opportunity to simulate a wide range of realities, from those occurring within the real world to those that can only be imagined.

### 4.2.2 The actual reality of the natural world

The natural world exists in an unlimited three-dimensional form that is governed by the laws of physics and subject to many other laws and customs. Individuals experience the natural world and learn how to interact with it from an early age. While no individual fully understands all of the natural world, the laws that regulate the natural world are complete in and of themselves. While objects in the natural world are subject to change, this change follows predictable patterns. This is what is considered to be reality in the natural world.

NOTE The natural world as experienced by a user is referred to as the "real world".

### 4.2.3 Virtual reality

#### 4.2.3.1 General

Virtual reality is generally used to describe a reality totally created within an information and communications technology (ICT) system, whether or not the reality is based on the natural world or the real world.

NOTE 1 The concept of a virtual continuum recognizes that as long as a human user is involved, there will be some physical elements of the real world involved directly. However, the term "virtual reality" focuses on the environment and reality that is created within the ICT system that the user is interacting with in a real-world manner.

To produce virtual reality, an ICT system uses a set of rules to represent the laws of that reality and a means of rendering a virtual world that users can experience and interact with. As opposed to the real world, the set of rules governing a virtual world will usually be incomplete, missing at least some aspects of

their counterparts in the real world. Users need to learn both how to interact with a virtual world and the limitations on these possible interactions.

NOTE 2 While it is possible to model all the rules of a simple game, modelling the real world is necessarily incomplete and typically focuses on modelling a set of tasks from the real world. Therefore, the desirable level of completeness will be dependent on suitability for the task and consistency with user expectations.

#### 4.2.3.2 Third-person perspective

The earliest versions of virtual reality involved the user manipulating the representation of a person (or other object) on a computer display. While the display was able to present an artificially created reality in which the user could be intellectually immersed, the user was not physically immersed in the environment.

In a third-person perspective, the user is able to observe the person (or object) being manipulated as well as the environment in which it is interacting.

This makes the user more of a puppet-master than a direct participant in the environment.

#### 4.2.3.3 First-person perspective

In a first-person perspective, the user observes the environment being interacted with from the perspective of an individual that is immersed in the environment. While this can include the observation of some simulated parts of the user (e.g. hands, arms, feet), the user usually does not observe a full representation of themselves within the environment (e.g. unless viewed in some reflecting surface of the environment).

This makes the user more of a direct participant in the environment.

### 4.2.4 Augmented reality

Augmented reality is generally used to describe the combination of elements in the real world with elements generated and contained only within the ICT system. This is often done by overlaying computerized projections on a real-world environment. These computerized projections do not have to follow the laws of physics of objects within the real-world environment; however, they are intended to be located within the same physical space as the real-world environment. While augmented worlds are generally intended to be experienced as a single unified reality, users need to be able to learn how to interact with the virtual components of this augmented reality, including limitations on these interactions.

### 4.2.5 Mixed reality

Mixed reality is often used similarly to augmented reality to describe the combination of elements in the real world with elements generated and contained only within the ICT system.

Mixed reality recognizes that there is a continuum of possible realities that spans between the complete reality of the natural world and a complete virtual reality. While individuals regularly deal only with the natural world, it is not possible to deal only with a virtual world. This is because a virtual world is created within the natural world and the actual interactions of its users are still governed by the laws of the natural world, even if they are interpreted differently within the virtual world.

## 4.3 Modalities

### 4.3.1 Multi-modal and multimedia

The natural world makes use of all of the human senses. Interacting by making use of a particular human sense is referred to as interacting within a particular modality. Traditionally, the five main modalities are visual, auditory, haptic (tactile), olfactory (smell) and gustatory (taste).

NOTE 1 Balance and proprioception can potentially be added to the list of modalities that are relevant to immersive environments.

Virtual and augmented realities attempt to make use of as many human senses as possible. Currently, this involves visual, auditory and haptic sensations. It is beyond the capabilities of current technology to use olfactory or gustatory sensations. This is especially due to the long latency of those sensations when perceived by a human, which does not allow for quick changes to be recognized.

The natural world is multi-modal in that all objects in the natural world can be simultaneously experienced via all available senses. In virtual worlds, it is important to ensure that objects can be simultaneously interacted with in all available modalities. Virtual worlds often have limitations on the extent of their support of multi-modality.

The focus of traditional ICT systems is on multimedia, in order to choose individual media to use for different pieces of content that can "best" be used to present the content in an engaging, effective, efficient and satisfying manner.

The focus of immersive environments is to increase the realism of the immersive experience.

The following subclauses on modalities focus on the user's perspective, thus they deal with inputs to the user and outputs of the user, rather than inputs to the systems and outputs from the system.

### 4.3.2 Visual

#### 4.3.2.1 Visual inputs to the user

The user can see the (natural, augmented or virtual) environment either as a projection on space surrounding the user or via some form of head-mounted display. While a head-mounted display can be more flexible in how it visually represents the environment, it can be less natural for users not used to wearing similar head-mounted gear. Even special glasses can be a distraction to users who do not normally wear glasses.

Visual scenes can be created either from three-dimensional photos or from computer-generated scenes or from a combination of these sources.

Major concerns include:

a) the amount of physical intrusion on the user (e.g. the need for devices mounted on the user);

b) the quality (realism) of the visual scenes;

c) the ability for scenes to be updated in real time as the user moves within the immersive environment;

d) occlusion of key elements of the real world;

e) support for users with low or no vision or no stereo vision.

#### 4.3.2.2 Visually recognized outputs of the user

The use of cameras can be used to track the user's eyes, head and other body parts.

NOTE The particular body parts to be tracked will depend on the nature of the immersion.

While visual eye tracking and haptic head tracking is available with head-mounted displays, more complete visual tracking generally requires devices mounted in the environment rather than attached to the user.

Visual tracking of three-dimensional orientations and movements generally involves the use of more than one visual sensor.

Major concerns include:

a) the amount of physical intrusion on the user (e.g. the need for devices mounted on the user);

b) the precision of the physical tracking possible when analysing the results of the cameras;

c) the ability of visual tracking to be used in real time as the user moves within the immersive environment.

### 4.3.3 Auditory

#### 4.3.3.1 Auditory inputs to the user

The user can hear the (natural, augmented or virtual) environment either as a projection in the space surrounding the user or via some form of headphone or hearing device. While a headphone or hearing device could be more flexible in how it visually represents the environment, it can be less natural for users not used to wearing similar head-mounted gear. Some hearing aids can have difficulties when used with headphones, while others make use of wireless technologies to avoid the need for headphones.

Auditory inputs can be created either from recordings or from computer-generated sounds and speech or from a combination of these sources.

Listening to sound from three-dimensional sources involves the use of stereo (two or more separate audio sources).

Major concerns include:

a) the amount of physical intrusion on the user (e.g. the need for hearing devices worn by the user);

b) the quality (realism) of the auditory information as well as its projection into the immersive environment;

c) the ability for audio information to be updated in real time within the immersive environment;

d) occlusion of relevant real-world sounds;

e) support for users with no hearing or no stereo hearing.

#### 4.3.3.2 Auditory recognized outputs of the user

Microphones can be used to input auditory information and to physically track the user. While a microphone can be attached to the user or hearing devices worn by the user, or both, more complete auditory tracking generally requires microphones to be mounted in the environment rather than attached to the user.

Identifying the user's location and orientation in three-dimensional space involves the use of several sensors, for example several microphones.

Major concerns include:

a) the amount of physical intrusion on the user (e.g. the need for microphones mounted on the user);

b) the quality of the speech recognition processing;

c) the precision of the physical tracking possible when analysing the results of the microphones;

d) the ability of recognition and tracking to be used in real time as the user moves, speaks and makes sounds within the immersive environment;

e) environmental noise.

### 4.3.4 Haptic

#### 4.3.4.1 General

Haptics involves the physical properties of touch and movement. Whereas visual and auditory interactions can be one-directional, generally, haptic interactions involve simultaneous inputs and outputs.

#### 4.3.4.2 Haptic inputs to the user

While the visual and auditory modalities can easily be used to produce a wide range of inputs to the user, haptic inputs to the user are relatively limited and often require specialized devices. Although haptic outputs

of the user are very commonly used to interact with ICT systems, the range of haptic inputs to the user is often limited to very primitive feedback that such actions have been received by the system.

EXAMPLE 1 The user recognizes that a key on a standard keyboard is successfully pressed by experiencing the movement of the key until it is stopped when it reaches its lowest possible position. Likewise, the user recognizes when a button on a mouse is pushed. Even where this haptic feedback is available, auditory clicking is often used to provide additional feedback.

The most commonly used haptic input to the user (apart from the physical device itself) is vibration. Such vibrations need to be suitable for human perception. Common frequencies used in mobile devices are 130 Hz to 180 Hz. For vibrations, frequency, amplitude and body location(s) in contact with the vibrating device are parameters to be taken into account. The amplitude can be modulated to create different experiences, as long as these differences are sufficient for detection, including when the person is moving. Different body locations can be used to convey information (e.g. vibration belt or bracelets for navigation), as long as the fact that different parts of the body have different sensitivity to vibration is taken into account.

In the natural world, physical actions on an object always provide predictable haptic feedback (e.g. in terms of motion or physical resistance). Providing such feedback when interacting with a virtual object usually requires a specialized device that can provide the same types of feedback as the physical object that the virtual object represents. This can involve the haptic properties of:

a) position, shape and size;

b) stiffness;

c) surface friction, roughness and texture;

d) mass and perceived weight;

e) temperature.

Devices that can provide sensations that can simulate these properties tend to focus on very specific properties of very specific types of objects, for example braille displays.

Failure to simulate these properties can lead to inconsistent behaviours occurring in a virtual environment.

EXAMPLE 2 A user who tries to sit on a virtual chair is likely to fall onto the floor. A user who walks into a virtual wall is likely to walk right through it.

#### 4.3.4.3 Temperature

In traditional computer systems, temperature is seldom used to provide information to a user, because of the latency of the human in recognizing changes in temperature of a single location. However, in an immersive environment, there are many locations that can provide information via different temperatures. Likewise, the ambient temperature, if it is too high or too low for comfort, can have an effect on the user's ability to function.

When temperature is used to provide information:

a) the range of temperatures used should avoid potential harm (from excessively high or low temperatures) to the user;

b) meaningful differences in temperature should be large enough to be easily distinguished by the user.

#### 4.3.4.4 Haptic recognized outputs of the user

The main sources of user outputs (system inputs) in traditional ICT systems is often via the haptic modality (using keyboards and mice). However, the use of keyboards and mice is specific to interacting with computers and is not realistic when interacting with other types of objects in an immersive environment. Likewise, stylized gestures made on an ICT screen are limited to traditional ICT systems.

In virtual environments, haptic user outputs can take the form of natural gestures that would be used to interact with specific objects in specific ways. These natural gestures can be captured by multiple cameras

without the need for actual physical contact. Placement of the cameras is most easily achieved in a specialized environment.

In mobile environments, gestures and movements are an important interaction modality. Gestures can be made both on a device and with a device (including full-body movements). Such gestures can be detected through a camera or through sensors, such as compass or magnetometer, accelerometer, GPS and different types of indoor location systems (connected via wireless technology). When detecting user gestures and movements, it is important to consider the precision of the sensors in relation to the type of movements to be detected.

## 4.4 Three dimensions

### 4.4.1 General

Both natural and virtual worlds exist in three-dimensional space (length, width, height). There is a distinction, however, in how this space is realized.

In the natural world, within the limits of physical laws and capabilities, a user is able to navigate to any location that is not currently occupied by another object. The user is also able to interact with objects, including moving them, using all three dimensions.

Immersive environments (including virtual worlds) can go beyond natural space to realize user interactions.

### 4.4.2 3D in specialized environments

Many immersive environments make use of specialized devices to provide a multi-modal experience. These specialized devices are often installed in a facility (such as a room or building) which limits the actual (natural) physical space available to the immersive environment. This can result in a disjunction between distances that a user can actually physically travel (in the natural environment housing the immersive environment) and the distances that the immersive environment is simulating.

EXAMPLE While an immersive environment can virtually represent an entire city through which the user is walking, the user cannot actually physically walk the corresponding real distance without additional special equipment, due to the actual size of the facility within which the immersive environment is physically located. However, the use of the specialized environment allows the mounting of cameras that can visually observe the movements of the user through the environment and allows the projecting of images of the virtual environment, lessening the need for devices being physically attached to the user to provided interactions with the immersive environment.

### 4.4.3 3D in augmented environments

Augmentation can take place anywhere in the natural environment, but doing so can limit the availability of devices that are sufficiently portable to be used in some locations.

EXAMPLE When using augmented reality to aid a person in exploring a city, the user can be limited to the use of some form of head-mounted display that overlays images from the user's immediate natural environment and a limited amount of haptic sensors that can easily detect the user's physical motions in that natural environment. It is unlikely that there will be devices that can visually observe the user as the user walks through the city.

## 4.5 Issues with interactions in immersive environments

### 4.5.1 General

Ergonomics is concerned with the well-being and performance of the user. This includes concern for usability, user experience and freedom from harm (e.g. motion sickness or accidents). These different aspects interact with one another in an immersive environment.

NOTE 1 While usability and freedom from harm concerns can lead to the immersive environment providing important notifications and other forms of user assistance, concerns for naturalness and realism of user experience can limit the ways in which these notifications and other forms of user assistance are provided to the user.

NOTE 2 While not applicable to all immersive environments, it can be more natural to have the environment act like a friend in providing advice to the user rather than it just presenting notifications in the way typical computer applications do.

The ergonomics of immersive environments can be organized into the following high-level categories, each of which can be further subdivided:

a) roles of the immersive environment;

b) immersion;

c) user interactions with an immersive environment;

d) user–user interactions within an immersive environment;

e) context awareness of the immersive environment.

Each of these categories is considered in the following clauses, which discuss human-system issues and provide guidance unique to immersive environments.

Annex A provides information on other ergonomic and related standards relevant to immersive environments.

# 5 Guidance on some roles of immersive environments

## 5.1 Roles of immersive environments

To address a wide range of technology applications, three main roles of immersive environments that can apply have been identified that each have their own unique ergonomic issues:

a) escaping reality;

b) enhancing reality;

c) changing reality.

Each of these roles of immersive environments is considered in the following subclauses, which discuss human-system issues and guidance unique to immersive environments.

## 5.2 Escaping reality

### 5.2.1 General

Immersive environments can create imaginary alternative realities that allow the user to escape (intellectually and partially physically) from the real world.

Virtual reality systems can provide immersive environments that are significantly different from the real world, including realities that are not consistent with the real world.

Augmented reality systems can provide immersive environments that add imaginary features that appear to exist and act within the real world.

### 5.2.2 Limiting the escape from reality

a) The immersive environment should provide distinct actions for entering the immersive environment and for exiting the immersive environment and returning to reality.

NOTE 1 This is important to help the user to distinguish between escaping from and re-entering reality.

b) The immersive environment should provide assistance to the user in identifying appropriate times for disengaging with or pausing interactions with the immersive environment.

NOTE 2 Various conditions that can indicate the appropriate time include:

1) at the end of a pre-defined activity;

2) after spending the amount of time that was available for the immersive activity;

3) when it is important for the user to attend to the needs of the real world.

### 5.2.3 Recognizing that the user remains part of the real world

The immersive environment should help to ensure that the user does not take any actions in the immersive environment that will have negative consequences in the real world.

NOTE This includes avoiding both physical and other forms of harm. Problems could occur if the user is not aware of potentially harmful situations that are present in the real world in which the immersive environment is situated.

The immersive environment should alert the user if it is necessary to respond to any identifiable emergencies in the real world, and then either disengage with the user to avoid distracting the user from making any necessary responses or assist the user in making suitable responses to the real-world situation.

While immersion and presence are major objectives of immersive environments, it is important for the user to still be aware of any real-world situations that can justify disengaging with the immersive environment in order to deal with them in a timely manner. Problems can occur if the user misses or delays dealing with such situations.

### 5.2.4 Ensuring that escaping reality does not change the real world

The immersive environment should ensure that the user recognizes the difference between being in the imaginary alternative reality and being in the real world.

NOTE 1 Problems can occur if the user starts to believe conspiracies or "alternative facts" from the imaginary immersive environment.

NOTE 2 Problems can occur if the user behaves in the real world in ways that are only allowed in the imaginary immersive environment.

EXAMPLE When exiting the immersive environment, the user is given the following message: "Re-entering the real world – a different reality and set of rules applies."

### 5.2.5 Re-entering the immersive environment

The immersive environment should provide the user with a means of saving the current state of the environment.

The immersive environment should provide the user with a means of re-entering the immersive environment in a saved state.

## 5.3 Enhancing reality

### 5.3.1 General

Immersive environments can augment reality to aid users in understanding and interacting with the real world.

EXAMPLE Travel guides and cultural interpretation systems can make use of augmented reality to guide and inform users.

Augmented reality systems can provide immersive environments that add commentaries and instructions relating to objects and locations within the real world.

### 5.3.2 Managing the information provided when enhancing reality

The immersive environment should ensure that information it provides about the real world does not intentionally mislead the user.

The immersive environment should ensure that the user realizes the limitations of the information about the real world that it provides.

### 5.3.3 Providing user control of how and when enhancements are presented

The immersive environment should ensure that the user is not distracted from the real world by the unwanted presentation of information.

The immersive environment should ensure that the user does not miss information that is needed to assist the user in interacting with the real world.

## 5.4 Changing reality

### 5.4.1 General

Immersive environments can change the user and/or assist the user in changing the real world.

EXAMPLE 1 Immersive environments can be used for education and training that is intended to change the user's knowledge and skills.

EXAMPLE 2 Immersive environments can be used to aid users in interacting (locally or remotely) with complex systems such as in performing complex medical procedures and controlling various types of equipment and facilities.

Virtual reality systems can provide immersive environments in which users can learn and conduct simulations and virtual experiments without having actual facilities and equipment in the real world and without the consequences of performing dangerous or potentially irreversible actions.

Augmented reality systems can provide information, predictions and heightened physical capabilities to assist the user in interacting (locally or remotely) with objects and controls in the real world.

### 5.4.2 Distinguishing between actions that affect the immersive environment and those that affect the real world

The immersive environment should help the user to avoid harmful actions.

NOTE This can include helping the users to recognize:

a) where their actions will affect the real world;

b) actions that cannot be reversed;

c) actions that can result in harm.

### 5.4.3 Providing user access to information that supports interactions

The immersive environment should provide appropriate user assistance to support interactions.

NOTE Basic user assistance can include:

a) suitable error avoidance and error-handling support;

b) a means to obtaining help and information regarding possible interactions;

c) a means to reviewing the history of the interactions which led to the current situation.

# 6 Guidance on immersion

## 6.1 Contributing to immersion

Immersion is a sensory experience that engages users with a virtual or mixed reality.

Various aspects of immersion include:

— spatial immersion, where the immersion focuses on a three-dimensional location within the immersive environment;

— temporal immersion, where the immersion focuses on the current point in time, which has been led up to by a series of experiences within the immersive environment, and where this point precedes future potential experiences;

— emotional immersion, where the user feels engaged within the immersive environment.

Immersion depends on:

a) the completeness of the virtual or mixed reality;

b) the naturalness of the virtual or mixed reality;

c) the involvement of the user in the virtual or mixed reality;

d) the production of an optimal user experience.

Additionally, the suitability of the immersion depends on freedom from harm.

## 6.2 The completeness of the virtual or mixed reality

### 6.2.1 General

Regardless of the technologies involved, immersion takes a user from the real world and places the user within a virtual or mixed reality. Immersion only takes place within the boundaries and limitations of this virtual or mixed reality. The boundaries and contents of this reality limit the ability for a user to be immersed.

### 6.2.2 Supporting three-dimensional (virtual or mixed) space

The immersive environment should support the user's apparent navigation within three-dimensional virtual (or mixed) space, regardless of the physical actions involved in this navigation.

The immersive environment should ensure that the dimensions and behaviour of objects within three-dimensional virtual (or mixed) space are realistic based on the expectations of the virtual or mixed reality.

NOTE In mixed realities this can involve the system maintaining a contextual awareness of the objects.

### 6.2.3 Supporting realistic timings

The immersive environment should ensure that time moves consistently with the expectations of the virtual or mixed reality.

For the purposes of some realities, the elapsed time may be compressed or expanded in relation to the passage of time in the real world.

The immersive environment should ensure that actions within the system take realistic amounts of time based on expectations of reality in the immersive environment.

NOTE This can be accomplished by combining fast processing with appropriate delays to simulate real-time actions in the virtual or mixed environment.

## 6.3 The naturalness of the virtual or mixed reality

### 6.3.1 General

Immersion involves making the virtual or mixed reality seem natural to the user. This involves de-emphasizing the role of the computer and any peripheral devices with which the user interacts and focusing on natural user interface interactions with objects that "naturally" belong in the virtual or mixed reality.

Where technical limitations could limit the naturalness, the use of perceptual illusions can help to maintain naturalness in the interface and interactions.

NOTE ISO/IEC 4944 provides guidance on evaluating the naturalness of a user interface.

### 6.3.2 Maximizing the use of natural user interactions

The immersive environment should maximize the use of natural user interactions to increase the reality of the experience.

NOTE This is often done by providing support for multi-modal interactions.

### 6.3.3 Using perceptual illusions

When there are technical limitations on the range of interactions possible, the immersive environment should create perceptual illusions that will maintain the maximum amount of reality.

NOTE Perceptual illusions can be used to break the correspondence between actual physical properties and the user's interpretation of those physical properties, by using one type of sensory perception (e.g. vision) to override another type of sensory perception (e.g. feelings of motion).

EXAMPLE Rotating the view of the environment with every step that is taken can provide the perceptual illusion of walking long straight distances within a limited space, by requiring the user to keep physically turning while walking in order to maintain the same orientation with the environment. However, it is important that this rotation does not lead to motion sickness.

The immersive environment should avoid triggering adverse reactions (e.g. motion sickness) with the perceptual illusions that it creates.

### 6.3.4 Synchronization of the presentation of information

The immersive environment should:

a) respond in real time to user inputs;

b) synchronize information presented in various modalities;

c) avoid creating situations that could result in motion sickness.

## 6.4 The involvement of the user in the virtual or mixed reality

### 6.4.1 General

Immersion concerns the active involvement of the user in the virtual or mixed reality.

NOTE Some aspects of this active involvement are sometimes referred to as "user engagement".

### 6.4.2 Supporting the user's sense of presence

The immersive environment should engage the user by supporting the user's sense of presence within the environment.

NOTE This can be accomplished regardless of whether it involves first-person or third-person involvement.

### 6.4.3 Supporting flow of user involvement

The immersive environment should support the flow of user involvement within the virtual or mixed reality.

NOTE This can be supported by:

a) providing meaningful tasks within the environment;

b) focusing on the virtual or mixed reality (rather than the real world).

### 6.4.4 Supporting user trust

The immersive environment should encourage the user to trust that interacting with the virtual or mixed reality will not result in harm from use.

While a virtual or mixed reality cannot protect the user from all forms of harm, it is important that interactions with the virtual or mixed reality do not add additional risks of harm from use.

## 6.5 The production of an optimal user experience

### 6.5.1 General

Immersion involves allowing the user to experience the virtual or mixed reality to the fullest extent possible.

### 6.5.2 Focusing on intended user experience

The immersive environment should support and encourage the intended set of user experiences.

NOTE This can involve both the inclusion and exclusion of (un)important or distracting objects and actions to be supported within the environment.

### 6.5.3 Handling interactions and experiences realistically

The immersive environment should realistically handle successful and unsuccessful user interactions and experiences.

NOTE While the focus of most systems is on facilitating successful interactions, the real world includes both successful and unsuccessful interactions.

## 6.6 Avoidance of harm from use

### 6.6.1 General

Immersion involves the whole user committing to the immersive experience. This involves trusting that the immersive experience will not harm the user, as detailed in the following subclauses.

### 6.6.2 Avoiding physical harm resulting from an immersive environment

The immersive environment should avoid physical discomfort and sickness resulting from user interactions, including:

a) repetitive strain injuries, especially those from making repeated "unnatural" actions;

b) posture strains from long periods of being in the same position and from abnormal postural positioning used to interact with the immersive environment;

c) additional strain and discomfort from wearing or interacting with specialty devices that are used to create the immersive environment;

d) simulator sickness, which is similar to motion sickness, but can occur without any actual motion of the subject;

e) binocular stress, which is the dissociation of accommodation and convergence when using stereoscopic displays;

f) mismatch between the optical properties of the system and optical properties of the user;

g) stress or damage to the user's hearing due to excessive sound volume.

### 6.6.3 Managing emotional effects of an immersive environment

Immersive environments can provide very realistic and compelling experiences, which can have significant emotional effects on their users.

While developers can wish to increase use of their immersive environments, it is important that the user does not become dependent on escaping to the immersive environment, especially at inappropriate times.

The immersive environment should take action to avoid becoming addictive.

EXAMPLE Each time the user enters the immersive environment, a message is presented identifying the amount of time that the user has spent in the environment during the last week.

The immersive environment should adhere to ethical constraints as well as being consistent with other physical and intellectual expectations.

The immersive environment should ensure that the levels of fear, anxiety, stress and other emotional responses to an immersive environment are within reasonable limits for the user to be able to handle.

### 6.6.4 Avoiding harm to the physical environment

The immersive environment should avoid situations where users can harm the real environment in which the immersion is taking place.

## 7 Guidance on user interactions within an immersive environment

### 7.1 User interactions with an immersive environment

While it is possible to provide an immersive environment in which the user is largely a passive observer (such as a simulated amusement park ride), most immersive environments create immersion by the user interactions that they respond to.

The main types of interactions between an individual user and an immersive environment include:

a) interactions to control properties of the immersive environment;

b) interactions to obtain information within the immersive environment;

c) interactions to move within the immersive environment;

d) interactions with inanimate objects within an immersive environment;

e) interactions with interactive objects within an immersive environment.

Each of these types of interactions is considered in the following subclauses, which discuss human-system issues that are unique for immersive environments.

## 7.2 Controlling properties of an immersive environment

### 7.2.1 General

While the majority of user interactions are focused within the immersive environment, there are some controlling interactions that necessarily take place outside the immersive environment because they are intended to control the properties of the immersive environment, even if they are able to be initiated from within the immersive environment.

### 7.2.2 Providing a suitable range of control

The immersive environment should provide a means of controlling its properties in a manner that is consistent with the intended roles of the immersive environment.

The immersive environment should make recognizable for the user the capabilities for and limitations on controlling its properties.

NOTE 1 If the capabilities are not recognized, then they will not be used.

NOTE 2 If limitations are not recognized, then the user can become frustrated when encountering unexpected limitations.

The immersive environment should allow users to pre-select how and how much they wish to engage with interactive objects in reality.

### 7.2.3 Transitioning between controlling the immersive environment and acting within it

The immersive environment should make the transition between controlling the properties of the immersive environment and acting within it readily available and easy to use.

The progression of time in the immersive environment should be able to be paused to support controlling its properties.

NOTE This will allow the user to carefully consider any control actions without being affected by unnecessary time pressures.

### 7.2.4 Supporting the naturalness of the controls

The immersive environment should make the means of transitioning to controlling the properties of the immersive environment both natural and distinctive from other actions that the user could perform when acting within the immersive environment.

The actions involved in controlling the properties of the immersive environment should be natural and consistent with actions that can be performed within the immersive environment.

NOTE This can help to maintain the user's focus on and belief in the reality of the immersive environment.

## 7.3 Obtaining information within an immersive environment

### 7.3.1 General

Users obtain information within an immersive environment by:

— using their senses within the immersive environment;

— determining their current position within the immersive environment;

— identifying objects within the immersive environment;

— receiving feedback to the actions they perform within the immersive environment;

— taking special actions to obtain particular information within the immersive environment.

### 7.3.2 The real-time nature of an immersive environment

Due to the dynamic real-time nature of an immersive environment, it is likely that the user will miss some of the information being presented by the immersive environment.

The immersive environment should focus the user's attention on the presentation of essential and particularly important information that could otherwise be missed.

### 7.3.3 Multi-modality in an immersive environment

While immersive environments typically make use of multi-modal interactions, there are limits to the types of interactions that are available in some modalities. For example it is often difficult to provide realistic tactile and haptic feedback to user actions.

While it is important to present information in the appropriate modalities wherever possible, the immersive environment should ensure that all essential and particularly important information be presented at least in some modality.

The immersive environment should avoid creating feelings of disorientation that can arise from the disconnect between what the brain thinks the body should be feeling and what it actually feels.

NOTE A visual representation of the user or of parts of the user (e.g. the user's hands) can help to limit potential disorientation.

### 7.3.4 Avoiding sensory overload in an immersive environment

The immersive environment should ensure that the use of modality shifting does not result in the overloading of information in any individual modality, unless that is a specific goal of the immersive environment.

NOTE 1 Modality shifting involves shifting inputs and/or outputs normally performed in one modality to another modality. This is often done for accessibility purposes. Modality shifting could be necessitated because of limitations in the capabilities of some modalities to be used, either by the system or by the user.

NOTE 2 It can be useful for the user to be able to simplify the contents and information in the immersive environment to avoid sensory overload.

## 7.4 Moving within an immersive environment

### 7.4.1 General

Some movements of a user within an immersive environment include:

— entering and exiting the immersive environment;

— changing the direction of sight and adjusting the viewing angle within the immersive environment;

— navigating through the immersive environment;

— planning and following a route through the immersive environment;

— moving the position of the user within the immersive environment;

— turning and changing the direction of travel;

— controlling the speed of movement;

— avoiding and dealing with collisions within the immersive environment;

— concurrently moving and interacting with objects within the immersive environment.

### 7.4.2 Providing a suitable set of movements

The immersive environment should support the full range of essential and important movements of the user within the environment.

NOTE 1 The range of essential and important movements will depend on the goals and the role of the immersive environment.

The immersive environment should ensure that the user is able to recognize the capabilities for and limitations of movements within an immersive environment.

NOTE 2 If the capabilities are not recognized then they will not be used.

### 7.4.3 Supporting the naturalness of movements

The immersive environment should ensure that there is a clear and consistent correspondence between the actual actions performed by the user and the resulting movement of the user within the immersive environment.

The immersive environment should ensure that the user actions needed to create movements are as natural as possible and as consistent as possible with movements that can be performed within the immersive environment.

### 7.4.4 Providing suitable feedback on the success of movements

The immersive environment should provide immediate and suitable feedback to inform the user of the success or failure of attempts to move within the immersive environment.

## 7.5 Interacting with objects within an immersive environment

### 7.5.1 General

Some typical interactions with objects within an immersive environment include:

— selecting an object;

— operating an object;

— picking up an object;

— setting down an object;

— throwing an object in a particular direction;

— positioning an object;

— rotating an object.

Some additional interactions with objects within an immersive environment include:

— adding virtual objects to the environment;

— hiding real world objects in a mixed environment;

— adjusting the properties of an object, including:

  — resizing the object;

  — colouring the object;

  — removing a virtual object from the immersive environment.

### 7.5.2 Providing a suitable set of interactions

The immersive environment should support the full range of essential and important interactions between the user and the objects within the environment.

NOTE 1 The range of essential and important interactions will depend on the goals and the role of the immersive environment.

The immersive environment should ensure that the user is able to recognize the capabilities for and limitations of interactions between the user and the objects within an immersive environment.

NOTE 2 If the capabilities are not recognized then they will not be used.

### 7.5.3 Supporting the naturalness of the interactions

The immersive environment should ensure that there is a clear and consistent correspondence between the actual actions performed by the user and the resulting interactions of the user with objects within the immersive environment.

The immersive environment should ensure that the user actions to create interactions are as natural as possible and as consistent as possible, with actions that can be performed within the immersive environment.

### 7.5.4 Providing suitable feedback on the success of interactions

The immersive environment should provide immediate and suitable feedback to inform the user of the success or failure of attempts to interact with objects within the immersive environment.

## 7.6 Interactions with interactive objects in the immersive environment

### 7.6.1 General

Some typical interactions with interactive objects within an immersive environment, beyond those with inanimate objects, include:

— communicating with the object;

— adjusting controls on the object;

— initiating or ending some action of the object.

NOTE Real-world objects that are part of a mixed reality will respond to real-world user actions, whether or not their response is captured by the system that creates the immersive environment.

### 7.6.2 Providing a suitable set of interactions

The immersive environment should support the full range of essential and important interactions involving interactive objects within the environment.

NOTE 1 The range of essential and important interactions will depend on the goals and the role of the immersive environment.

NOTE 2 These interactions can be in response to the actions of users or other interactive objects or can be initiated by the interactive object itself.

### 7.6.3 Recognition within the immersive environment

The immersive environment should immediately recognize the results of interactions by interactive objects (whether in virtual reality or mixed reality).

The immersive environment should provide immediate and suitable feedback to inform the user of the success or failure of interactions by interactive objects within the immersive environment.

# 8 Guidance on supporting multiple users within an immersive environment

## 8.1 User-user interactions within an immersive environment

In addition to the other types of interactions, an immersive environment can also make user-user interactions possible. User-user interactions involve:

a) who can interact within the immersive environment;

b) controlling individuals' locations within the immersive environment;

c) social interactions that are apparent to all users;

d) personal interactions that are limited to some users.

## 8.2 Interacting with others within the immersive environment

### 8.2.1 General

In an immersive environment, one real user could be provided the means to interact with:

— one or more other individual real users;

— one or more groups of real users;

— one or more virtual individual persons within the environment;

— a mix of both real and virtual individuals within the environment;

— one or more groups of virtual people within the environment;

— the environment.

In multi-user environments it is important to recognize that:

a) real users can be unpredictable;

b) real individuals differ in more ways than can be readily modelled by a system;

c) people within a group move and behave in a manner that is influenced by the overall group's movement and behaviour.

### 8.2.2 Making expectations clear to real users

The immersive environment should make all real users aware of the expectations relating to their interactions with other users within the immersive environment.

### 8.2.3 Modelling virtual people

The immersive environment should clearly model:

a) the level of involvement expected of each virtual person and of groups of virtual people;

b) the main traits and actions that are modelled for each virtual person and each group of virtual people.

NOTE Immersive environments often attempt to model virtual people sufficiently to make them and their actions appear indistinguishable from real users. Thus, the traits and actions of real users that the immersive environment recognizes and supports are often also modelled for virtual persons.

## 8.3 Controlling an individual's location within the virtual environment

### 8.3.1 General

Within a mixed reality system, it is typical for each individual user to independently control the view that they experience.

Within a virtual reality system, the view that an individual user experiences can be:

— individualized by each "independent" user (active viewing), where each user can move and act within the environment independently, only needing to interact with other users when they come in contact with one another;

— controlled by a single guiding user (passive viewing), especially when using the virtual environment for cooperative tasks, for example guided tours and the design or evaluation of systems.

NOTE 1 It is possible to change the person who is guiding the experience.

NOTE 2 While one person guides the experience, other interactions with the environment can either be reserved to that person or made available to all users. In any case, it is typical to provide a means for all users to communicate with each other.

NOTE 3 It is possible for the immersive system to simulate a guiding user.

### 8.3.2 Maintaining the latest state of the environment

The immersive environment should model the latest state of the environment, including the location and actions of all individuals and the results of their actions.

### 8.3.3 Avoiding disorientation caused by the actions of other users

When a guiding user changes location within the environment, the immersive environment should avoid causing other users to experience effects-related disorientation.

When abrupt changes of location are initiated by a guiding user, the immersive environment should:

a) warn users who are affected by unexpected changes of location;

EXAMPLE When a guiding user causes a change of location to another user, the other user is warned of this change by the immersive environment going dark for a moment before the other user is transported to the new location.

b) re-orient the affected users once the change has taken place.

## 8.4 Simultaneously interacting with an object within the virtual environment

### 8.4.1 General

Within immersive systems that support multiple simultaneous users, it is possible for each individual user to independently attempt to interact with the same object.

Control of the object can be:

— maintained by the first individual to "touch" the object and who remains in contact with the object (first come, first served control);

— taken over by the most "powerful" user (prioritized control);

NOTE 1 This can be especially important in training and supervisory situations.

— negotiated between the users via their communications with one another (shared, single control);

— based on a combination of the actions of all users currently interacting with the object (joint simultaneous control).

NOTE 2 This complex control can make use of various factors to determine the results of the multiple users interacting, including the relative "strength", "power", "speed" and "skills" of different users.

### 8.4.2 Maintaining awareness of joint interactions

When individuals are interacting simultaneously with the same object within an immersive environment, the immersive environment should ensure that all users interacting with the object are aware of what is taking place.

### 8.4.3 Managing joint interactions

When multiple individuals can simultaneously interact with the same object, the immersive environment should ensure that:

a) the basis for determining control of the object can be understood by all users;

b) where control can be maintained by one or a pre-selected group of users, there is a means of managing which users currently maintain control;

c) the users are provided a means of communicating with one another to negotiate by whom and how the object is to be controlled;

d) the results of the interaction are obvious to all individuals within the immersive environment.

## 8.5 Social interactions supported by the immersive environment

### 8.5.1 General

"Social" interactions initiated by each user can influence the group of other users, including interactions that:

— change the environment (including objects within the environment) for all users;

— communicate between users (share information), without changing the environment (including discussing, debating, arguing, compromising, resolving conflicts and coming to agreement on issues).

Some typical social interactions include:

— greeting one another;

— gazing at one another;

— gesturing towards one another;

— communicating information with one another.

Additional types of social interactions include:

— taking turns;

— passing control between users.

### 8.5.2 Support for social interactions

In multi-user systems, the immersive environment should provide a suitable set of social interactions, in addition to the task-related interactions it provides.

#### 8.5.3 Awareness of social expectations

In multi-user systems, the immersive environment should make users aware of:

a) the social expectations that they are expected to follow;

b) any social taboos that they should avoid violating;

c) how to act appropriately in the immersive environment.

### 8.6 Personal interactions supported by the immersive environment

#### 8.6.1 General

"Personal" interactions are private interactions that take place between a set of individuals that:

— communicate between themselves (share information);

— only affect the individual users and do not affect other users or the rest of the environment.

#### 8.6.2 Support of personal interactions within an immersive environment

In multi-user systems, the immersive environment should:

a) provide a suitable set of personal interactions, in addition to its social and task-related interactions;

b) make the users aware of how to ensure that their personal interactions remain private.

## 9 Guidance on context awareness of the immersive environment

### 9.1 General issues with context awareness

Context awareness of the interactive system is an important component of providing an immersive experience. Context awareness occurs when an individual comprehends what is happening in their immediate environment.

Context awareness involves:

— the perception of elements in the environment within a certain time and space;

— comprehending the meaning of those elements;

— projecting their near-future status.

Some of the ergonomic issues with context awareness in an immersive environment include:

a) modelling the immersive environment and updating this model in real time;

b) relating the physical, artificial and mental model components of the immersive environment;

c) interacting with the real world.

### 9.2 Modelling the immersive environment and updating this model in real time

#### 9.2.1 Real-time modelling of the immersive environment

The immersive environment should present the user with a constantly updated model of the immersive environment.

### 9.2.2 Real-time modelling of the user

The immersive environment should continually monitor the user's positioning within the immersive environment and use this information to constantly update its model of the user within the immersive environment.

### 9.2.3 Real-time responses to user interactions

The immersive environment should identify any intended user interactions and respond to them in real time.

## 9.3 Relating the physical and mental components of the immersive environment

The immersive environment should model both its physical and mental components.

It is important to be aware of the cognitive space created in an immersive environment as well as the physical space. Semantic recognition of the environment surrounding the viewer can include the following:

a) Reinforcing: leveraging a real location that is inherently meaningful and supplementing it with virtual content appropriate to that location.

b) Reskinning: embellishing mundane real locations with compelling virtual content that a user already knows and loves, changing the real world to fit the needs of the virtual content and story.

c) Remembering: recognizing that while most of the real world can be mundane, the personal memories tied to specific locations are not, and providing a lever that can be exploited to make compelling experiences.

## 9.4 Interacting with the real world

### 9.4.1 General

Interaction with virtual, augmented and mixed environments takes place in a real environment. The particulars of the real-world environment can limit the characteristics of immersion that are suitable.

NOTE 1 The amount of context awareness will depend on the type of reality involved.

NOTE 2 In a mixed reality, there is also a difference between using mixed reality to augment the properties of natural objects and using it to create fully virtual objects. Natural properties of a natural object could limit the ability of virtual properties to augment the natural object.

### 9.4.2 Awareness of the real world

The immersive environment should be aware of the real world in which it is taking place.

NOTE This can be accomplished by using sensors to examine the real world and/or by asking the user at the start of use a series of questions that help to identify potentially relevant components of the real world that can affect the interactions and experiences with the immersive environment.

### 9.4.3 Avoiding harm

The immersive environment should use its awareness of the real world to limit or discourage the user from getting into situations that could result in harm to the user, the system or the natural environment.

NOTE 1 While virtual reality environments are typically restricted to be safe, augmented and mixed environments, the real environments within which they occur can involve dangers for users.

NOTE 2 Some of the ergonomic issues related to possibilities of harm include:

a) occluding of information about potential dangers;

b) changes in the real environment that could present possible dangers;

c) running against an object in the real world which is not visible in the virtual environment;

d) requiring time-dependent interactions;

e) the mental load and other strains on the user.

NOTE 3 Stress related to emotional immersion has the potential to distract the user in a way that can be hazardous or, in the worst case, make the user totally ignore potential dangers.

### 9.4.4 Connecting with the real world

A mixed-reality environment should control the presentation of information to connect the user's experience of the real world with that of the virtual world.

### 9.4.5 Providing appropriate transitions between realities

The immersive environment should provide appropriate transitions between the user interacting with the real world and interacting with virtual components to maintain the immersive experience.

NOTE Appropriate transitions are those suitable for the task and in keeping with the goals and design of the immersive environment.

### 9.4.6 Dealing with boundaries

The immersive environment should make clear to the user any boundaries that it has and any physical boundaries from the real world that limit the user's movement.