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Computer graphics, image processing and environmental data representation — Augmented and virtual reality safety — Guidance on safe immersion, set up and usage

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 24, *Computer graphics, image processing and environmental data representation*.

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 and www.iec.ch/national-committees.

Introduction

Market research assessed the requirement for standards and guidelines to help shape best practice in the application and use of augmented reality (AR) and virtual reality (VR). AR/VR technologies are continuing to evolve, this document recognizes this by addressing relevant concepts that may be applied to future and emerging technologies, and this document supplies specific examples to illustrate various categories of concern that should be considered for safe use. Although platform and other AR/VR guidelines exist, this research pointed to a need to establish formalized industry standards for best practice guidelines for the safe usage of AR/VR across a broad range of domains. Following this market research, BSI consulted with many key stakeholders in the sector and ran workshops to discuss specific AR/VR standards ideas and to assess key priorities for standards development in this area. AR/VR health and safety (H&S) was unanimously a major area of concern for stakeholders, and one they felt could hold back the growth of the sector if not addressed.

H&S is a concern for all industry sectors, but in certain areas such as the built environment, military simulation, first responder training and manufacturing and utilities, adoption of AR/VR is being hindered because H&S is not being appropriately considered. This document will provide surety to AR/VR stakeholders that the technology can be used safely across sectors and by consumers.

Safe immersion is a key area of H&S concern for stakeholders. VR, in particular, can lead to users experiencing motion sickness and disorientation, and disconnects users from their immediate surroundings, these and other effects could cause serious safety concerns in many environments. There are various factors that contribute to this, including the design and development of content, the device set-up (e.g. device not correctly positioned on the users' head), the space in which the device is used, time spent immersed, and more. What may be considered as safe is also affected by the situation (e.g. home use vs industrial use) and the sector of activity (e.g. training in a call centre vs at height on a building site). This document will take the full gamut of AR/VR use into account to provide holistic guidance for the market.

For this document, sound and haptics are less significant than visual modes and are thus considered out of scope. Despite this, it is acknowledged that, particularly in industrial settings, accurate audio fidelity may be an important training consideration.

Our understanding of AR/VR safety is still developing so this document will initially provide guidelines for organizations and consumers to consider when using the technology, and in the development of content. This document will achieve this by describing risks and considerations of AR/VR use, provide guidance to mitigate these potential issues, and finally provide AR/VR specific templates and tools for risk assessment and reporting. Noting the rapid development of AR/VR technologies, this document will be updated at appropriate moments to reflect new technological developments if and when they introduce risks not previously considered. The annex materials provide particular considerations for:

a) AR and VR distinctly;

b) enterprise and consumer usage distinctly; and

c) within particular sectors/scenarios.

This document has been developed with consideration of the needs of stakeholders belonging to two main categories. These interests are categorized as such:

1) an enterprise perspective, consisting of organisations that are implementing or managing the use of AR/VR, and therefore providing guidance to employees on safe use practices. This enterprise perspective also encompasses technology manufacturers or other service providers; and

2) a consumer perspective, informing technology manufacturers how to ensure safe use of devices by end consumers, and informing consumers of risks they should be cognizant of (e.g. how VR may impact post-use motor skills).

The reality-virtuality continuum

Milgram and Koshono first conceptualised the VC from the real environment to the virtual environment[1]. Reality, AR, AV and VR are all positioned on the VC as shown in Figure 1.

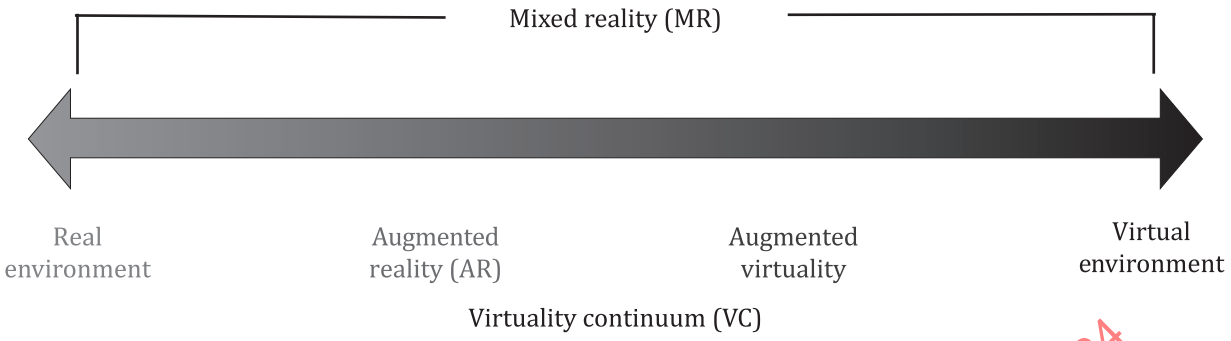


Figure 1 — Reality Virtuality (RV) Continuum (adapted from Milgram and Kishono[1])

The focus of this document is on AR and VR which are well-defined reality modes that have been in use for several decades.

Distinguishing virtual from real

In developing taxonomies for the VC, concepts of real and virtual images and objects also need to be considered. A real object has an objective existence, whereas in the VC context, a virtual object is computer-generated. Similarly, a real image has luminosity at the point where it appears to be located whereas a virtual image has no luminosity at its apparent position. These concepts are well established in optics[3].

Different aspects of distinguishing reality from virtuality are shown in Figure 2. The observer can view a real object (A) directly or indirectly via a real or virtual image. Further, a virtual object (AA) can be created by computer that can be viewed as a real image or virtual image in the case of a stereoscopic display. Modern head mounted displays may allow:

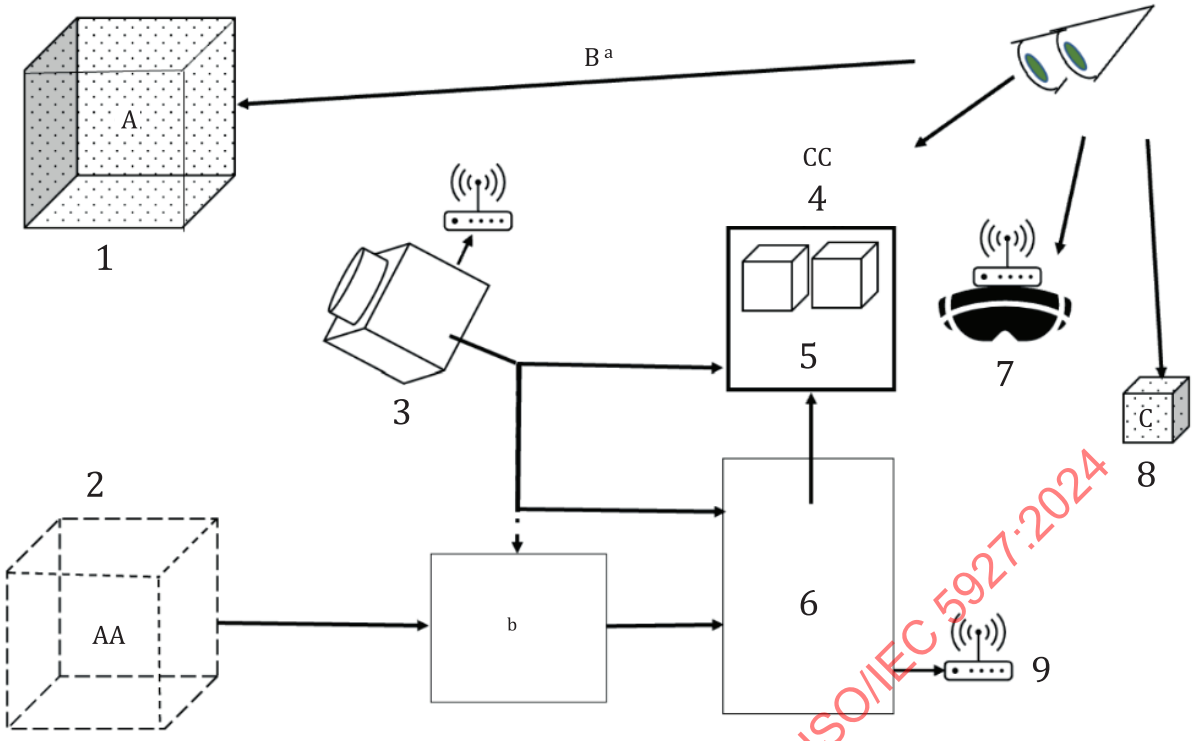
a) direct viewing of a real image of a real object;

b) indirect viewing of the same real object from a real computer synthesized image;

c) viewing of a real image from a virtual object; and

d) viewing of a virtual image simultaneously.

The HMD can access the camera and computer data via wireless technology or other similar technology.



Key

1 Real object / real image
2 Virtual objects (e.g. Created with a compute)
3 Sampling apparatus (e.g. Camera, sensor, mobile phone, etc.)
4 Non-direct viewing (synthesising display)
5 Real images
6 Computer with graphics capability
7 Head mounted display
8 Virtual Image (e.g. mirror image, holograms)
9 Wifi or Bluetooth® connection providing remote connections
a Direct viewing.
b Model: $T^2 = U^2 + V^2\ y{=}mc^2$.

Figure 2 — Different aspects of distinguishing reality from virtuality adapted from Milgram and Kishonol[1], and Stothard and Shiranai 2023[4]

Computer graphics, image processing and environmental data representation — Augmented and virtual reality safety — Guidance on safe immersion, set up and usage

1 Scope

This document specifies how augmented reality (AR) and virtual reality (VR) devices are to be set up and used in the enterprise workplace in a manner that ensures health and safety (H&S) is maintained, H&S consequences are understood, and additional risks are not introduced. Within this concept of safe usage, there is particular focus on guidance around safe immersion (time) and safety in the workplace.

This document defines the concepts of AR, VR, the virtuality continuum and other associated terms such as augmented virtuality and mixed reality. This document provides guidance on:

a) setting up AR systems;

b) setting up VR systems;

c) safe usage and immersion in AR systems both in the consumer and enterprise domains;

d) safe usage and immersion in VR systems both in the consumer and enterprise domains.

This document focuses on visual aspects of AR and VR. Other modes such as haptics and olfactory are not addressed within this document.

This document covers both the hardware (the physical AR/VR head mounted displays) and areas of visual stimulus (the environments and graphics displayed in those headsets). This document does not cover all possible visual stimulus scenarios; focus is directed toward those areas that are known to have implications on safe use. This specifically includes the source vection (visual illusion of self-motion in physically stationary AR/VR users) and/or motion (physical movement of AR/VR users) and associated safe use considerations.

NOTE AR/VR have some shared safety concerns, but many are distinct to AR or VR and a consumer or enterprise environment. As such all of these are in scope, and this document is structured to account for these differences.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 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/

3.1.1
augmented reality
AR
interactive experience of a real-world environment whereby the objects that reside in the real world are augmented by computer-generated perceptual information

Note 1 to entry: AR Systems are further defined in ISO/IEC 18039:2019.

[SOURCE: ISO 18038:2020, 3.2, modified — added note 1 to entry.]

3.1.2
augmented virtuality
AV
merging of real-world objects into virtual worlds.

3.1.3
consumer environment
comprising of the family and the related cultural, sociological and economic factors

Note 1 to entry: In this document, the Consumer Environment for AR/VR refers to individuals using AR/VR devices.

3.1.4
enterprise environment
people and systems are integrated into an organisation, such as a large business, classroom, or training environment

3.1.5
XR
real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables

Note 1 to entry: Within this document, XR is used as an umbrella term encapsulating AR, VR, MR and other environments

3.1.6
field of view
FOV
extent (in horizontal and vertical axis angles) of the observable world that is seen from the viewer's position

[SOURCE: ISO 23019:2022, 3.5.5]

3.1.7
mixed reality
MR
display continuum in which both real and virtual images are combined in some way and in some proportion

Note 1 to entry: Augmented reality (AR) and virtual reality (VR) are considered to be on the mixed reality continuum.

[SOURCE: ISO/IEC TR 23843:2020, 3.4]

3.1.8
real image
image which can be received on a surface

[SOURCE: ISO 10934:2020, 3.1.75.3]

3.1.9
virtuality continuum
VC
continuum of states from physical reality, through augmented reality, augmented virtuality, to wholly computer-generated virtual reality

Note 1 to entry: This is also known as the reality-virtuality continuum.

Note 2 to entry: The continuum of states is illustrated in Figure 1.

3.1.10
virtual image
image at an arbitrary viewpoint (3.1.4) that is generated by collecting visible photo information from real images

[SOURCE: ISO/IEC 23488:2022, 3.1.5]

3.1.11
virtual reality
VR
set of artificial conditions created by computer and dedicated electronic devices that simulate visual images and possibly other sensory information of a user's surrounding with which the user is allowed to interact

[SOURCE: ISO 9241-394:2020, 3.8]

3.1.12
visually induced motion sickness
VIMS
motion sickness-like symptoms induced by perceived motion within the visual environment, such as when watching movies and screen images of video games

Note 1 to entry: The symptoms can include dizziness, vertigo, sweating, odd feelings in the stomach, and nausea, which can progress to vomiting.

[SOURCE: ISO 9241-394:2020, 3.1]

3.2 Abbreviated terms

2D	two dimensional
3D	three dimensional
API	application programming interface
AR	augmented reality
AV	augmented virtuality
BLE	Bluetooth® [a] low energy
CGI	computer generated imagery
DOF	depth of field
FOV	field of view
GPS	global positioning system
H&S	health & safety
HMD	head mounted display
IPD	interpupillary distance
MR	mixed reality
OEM	original equipment manufacturer
PPE	personal protective equipment

RV	reality virtuality
SLAM	simultaneous localisation and mapping
SSQ	simulator sickness questionnaire
UVC	ultraviolet c
VC	virtuality continuum
VIMS	visually induced motion sickness
VR	virtual reality
VST	video see through
WHS	work health & safety

[a] Bluetooth® is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of this product.

4 AR/VR technologies

4.1 General

This clause describes enabling technologies for AR and VR and the classification of Head Mounted Displays that are the primary means of implementing AR/VR systems for the user.

4.1.1 AR enabling technologies

There are three key AR enabling technologies: tracking, display, and input devices[5]. These technological advancements, together with miniaturization, have enabled AR to become available with mobile devices and AR glasses. These devices feature precise location pinpointing and hardware components such as high-resolution cameras, accelerometers, gyroscopes and compasses[6]. Most smartphones and smart glasses can support AR. However, there are only a few platforms that support pure mixed reality[2]; for example, the holographic devices that integrate virtual and real objects. These technologies come together into various techniques to anchor the virtual objects to and over the real world.

Depending on the technologies used and the specific type of application, the anchor in the real world can be a physical object in the form of an image marker or a magnetic tracker at a predefined location in space. Location is determined by using GNSS (commonly referred to as GPS), Wi-Fi or Bluetooth beacons, inertial tracking or hybrid tracking that combines two or more techniques[5]. Image marker tracking is one of the most applied techniques in the scientific literature, as it is the simplest one, requiring a 2D or 3D printed marker on a paper sheet or cube. Due to its simplicity, it has limitations, such as the distance from the marker or having the marker exposed in the real world in the first place. Therefore, alternative already existing or emerging techniques are used, such as simultaneous localization and mapping (SLAM) used in robotics for autonomous location and operation[7]. Another technique named coarse relocalization relies on various sensor inputs (GNSS (GPS), BLE) to discover spatial anchors within 100 m of the device.

There are various software development kits for AR applications using proprietary application programming interfaces (APIs) that support the creation of AR applications for mobile devices.

4.1.2 VR enabling technologies

VR relies on many technologies including:

a) real-time 3D computer graphics;

b) wide-angle stereoscopic displays;

c) viewer (head) tracking;

d) hand and gesture tracking;

e) binaural sound;

f) haptic feedback; and

g) voice input/output[8].

For this document, sound and haptics are out of scope.

Modern VR systems generally use headset displays known as head mounted displays (HMDs) that are wearable devices providing some level of immersion. A taxonomy of HMD devices is shown in Table 1. These are classified based on criteria including:

— whether they use optical or video real world content;

— extent of immersion;

— whether they are opaque or transparent;

— and whether they enable real video to be added to CGI.

Classes 1, 6, and 7 from Reference [9] are not displayed here since they refer to large screen displays rather than HMDs.

Table 1 — Taxonomy of HMD devices and components (from[9])

Class	Description	View window on world	Optical or video real world content	Immersive – full, semi, non	Opaque/ transparent	Video reality added to CGI
2	HMD with capability to show video and CGI simultaneously.	No	Video	Full	Opaque	No
3	HMD with capability to see through to real world and show CGI simultaneously.	No	Optical	Full	Transparent	No
4	HMD with capability to show video of real world and CGI simultaneously.	No	Video	Full	Opaque	Yes
8	HMD with capability to see through to real world and show CGI simultaneously.	Yes	Optical	Non	Transparent	No
9	Hand-held mobile device (smartphone or tablet) with capability to show video of real world and CGI simultaneously.	Yes	Video	Non	Opaque	Yes

Modern portable AR/VR devices that include smartphones and tablets are included within class 4. These can be as simple as a cardboard screen attached to a smartphone.

4.2 Health and safety considerations

There are potential health and safety concerns associated with the use of VR. These include but are not limited to physical side effects such as eye soreness, trouble focusing, blurred vision, impaired hand-eye coordination, reduced depth perception, decreased reaction time, loss of balance and fatigue. Care should be taken when transitioning from engagement with VR back to the real world when operating machinery or driving vehicles[10].

Other potential risks around the use of VR include prolonged nausea, impaired posture, repetitive strain injuries, infections related to hygiene/sterilization issues, risk of falls and leg fatigue. Care is required to ensure equipment sterilization is appropriate and the environment is psychically conducive for VR use[10] (See Annex C).

If a person is experiencing respiratory ailments, eye injuries or disease, emotional distress, digestive issues, significant sleep loss or hangover effects, use of VR equipment should be avoided. If a person has a condition which may affect their wellbeing when interacting with particular stimuli, such as epilepsy, or may impact their perception of reality, such as dementia, care is required to ensure content is appropriate[11].

Privacy considerations need to be determined in both AR and VR use, especially around the collection of biometric identifiers[11].

5 Safe installation/set-up

5.1 General

This clause addresses the proper physical environments, hardware maintenance and installation of software and updates for AR and VR head mounted devices (HMD). These will be addressed for both AR and VR technology and in three different areas: general guidance, enterprise use and consumer use. While there are many vertical use cases (i.e. healthcare, manufacturing) for immersive and semi-immersive technology, they are beyond the scope of this document.

Excluded from consideration here are smart phones, laptops and other established interfaces to immersive environments.

When using a new technology, the user should take time to adapt. To ensure the best possible outcomes, it is recommended that the user has time to become familiar with the relevant interfaces and environments when first using an AR or VR device.

5.2 General risk factors to consider with safe installation/set up of AR and VR

As HMD devices from various manufacturers are different, users should follow all installation and preparation instructions necessary for safe operation of the product and included or bundled accessories. All physical attachments to the HMD including straps, lenses, battery packs, controllers, electrical or data cabling should be inspected prior to use. Device comfort and fit as well as the physical surrounds are integral to ensure safe use. Explanation of appropriate sizing, securing attachments (such as controllers), interpupillary distance (IPD) adjustment, luminance (brightness) levels and importance of the headset matching user's IPD, calibration, and collision mitigation measures should be provided to users. Unsecured equipment and accessories, such as controllers, may become loose projectiles during use, such as during thrusting movements.

The HMD should be balanced and centred, and the user should see a single, clear image once it is adjusted appropriately, otherwise they may increase their risk of losing balance, experiencing dizziness, straining their eyes and experiencing a negative impact on coordination both during and after use. Many devices have options to enable the use of prescription eyewear, but users should be informed that the use of eyewear in addition to the product may affect clarity (due to misalignment of headset lenses and eyewear lenses) and comfort (due to extra pressure on face imposed by eyewear consider using spacers) and increase the likelihood of injury, such as in the events of falls or other collisions.

For products with virtual boundary systems, warnings are needed so that the user can account for thrusting motions at or near the boundaries and that the virtual space should be free from physical hazards. It is recommended that an environmental risk assessment be performed prior to use of the device. Particular attention should be paid to the following:

— physical hazards such as furniture and other collision and trip hazards, including ceiling fans, stairs, light fixtures, cables, heat sources, and sharp objects;

— evenness of the use area surface, including bumps or other warping of the floor as this can lead to falls;

— device sensors which may experience interference if there are mirrors or other similar surfaces nearby;

— animals and other people who should be kept away from the immediate use area;

— tethered devices within the use area, including cables that may become entangled;

— ventilation within the user's area;

— temperature in the use area, reducing the risk of equipment overheating; and

— exit access in the case of fire.

For products with passthrough, or video see through (VST), camera features users should be informed that the camera-provided view of the real world may have latency, impaired depth perception, and other detriments to safe locomotion in the real world[12]. It is recommended that users do not move around their physical space while using the camera-provided view. If the user is expected to move around their physical space while using the camera-provided view, they need to do so briefly, slowly, and carefully, and never when navigating dangerous areas, such as near stairs.

Users should be notified of risks and injury associated with modifying the product and/or using non-Original Equipment Manufacturer (OEM) provided devices and software.

Users should be notified of eye strain and general discomfort including user characteristics such as age, sex, visual and vestibular senses, and the symptom profile of Visually Induced Motion Sickness (VIMS) (sometimes referred to as VR sickness or cybersickness) including visual stimulation, locomotion and operation times. VIMS is the industry-preferred term when referring to nausea whilst using XR technology

— The impact of vestibular function and postural balance in age demographic groups <12, ≥ 12, ≥ 18, ≥ 35, and ≥ 65 is considered in[13-15] while the impact of sex (male/female), hormones, age etc., is considered in[16].

— Visual stimulation refers to the amount of user directed movement across the six degrees of freedom; and the amount of content change within the simulated environment (slow/fast graphic change, low/high visual density).

— Locomotion can be thought of as how a user navigates the virtual environment including non-user-controlled vection (motion), controller, or physical human movement. Non-user-controlled vection motion: user not in control of locomotion e.g. rollercoaster, flying or driving.

— Controller: Joystick with constant movement or teleportation.

— Physical human movement: user rotation, physical walking or jumping is considered in[17,18]. Operation times can vary considerably depending on the reason for use. It is recommended that users are informed of the risks and are reminded to take regular breaks in order to minimize adverse effects, and also take a break immediately if they feel any adverse symptoms.

HMDs with integrated speakers should inform users of acceptable decibel levels, similar to sound warnings on phones and/or headphones.

5.3 Guidance on safe installation in the enterprise

5.3.1 General

There are some environmental requirements that are unique to the enterprise space and lead to the general consideration of employee risk when engaged in HMD work related activities.

5.3.2 Guidance on safe installation/set up of AR in the enterprise

AR HMDs offer a different set of considerations for safe set-up and use than VR HMDs. This is due to the nature of AR HMDs, which rely on overlaying, or augmenting, the user's view of the real world. While the user can still see their surroundings when using an AR HMD, there are some considerations that should

be specifically considered, notably in the enterprise space. These considerations include the following, in addition to those listed in subclause 5.2:

— Any devices worn in an enterprise or industry setting should comply with, or enable the use of, all respective safety regulations and devices (e.g. hard-hat standards, hearing protection, or eye protection).

— Environment lighting conditions should be assessed to ensure visibility of the AR HMD screen without causing a risk to the user due to low light conditions.

— Use of the AR HMD should not obscure or obfuscate the safe use of any equipment or devices due to screen opacity settings.

— An AR HMD should not be used in any environment where the application(s) running on the device may lead to user distraction from potential real-world hazards.

5.4 Guidance on safe installation/set up of VR in enterprise

Setting up VR for enterprise use has some specific requirements, in addition to those listed in 5.1, because VR HMD experiences typically totally obscure the real-world during use. Therefore, there should be a minimum of a one metre clear boundary around each deployment or play space. This is to ensure the user does not accidentally strike or impact an obstacle or other user while wearing a VR HMD.

6 Approach to risk management for usage in AR and VR environments

6.1 General

Risk management (see ISO 31000) should address the needs of the organization using an integrated, structured, and comprehensive approach. Guiding principles allow an organization to identify priorities and make decisions on how to manage the effects of uncertainty on its objectives. These principles should apply to all organizational levels and objectives, whether strategic or operational.

Systems and processes usually deploy a combination of various technologies and functionalities in various environments, for specific use cases. Risk management should consider the whole system, inclusive of technologies, functionalities and the environment.

AR and VR technology systems can introduce new or emergent risks for an organization, with positive or negative consequences on objectives, or changes in the likelihood of existing risks. They also can necessitate specific consideration by the organization. A risk management framework can assist the organization to integrate AR and/or VR risk management into its activities. An example framework relating to leadership and commitment is available in ISO 31000:2018, Figure 3.

Organizations should implement a risk-based approach to identifying, assessing, and understanding the AR and VR risks to which they are exposed, as illustrated in ISO 31000:2018, Figure 4, and take appropriate treatment measures in accordance with the level of risk. The success of the overall AR and VR risk management process of an organization relies on the identification, establishment and the successful implementation of narrowly scoped risk management processes on strategic, operational, programme and project levels.

6.2 Identification of risk sources

The organization should identify a list of risk sources related to the use of AR and VR technologies within the defined scope.

Risk sources can be identified within, but not limited to, the following areas:

— personnel (physical, cognitive, vision system, etc.);

— physical environment (heat, chemicals, noise, physical hazards, etc.);

— data (eye tracking, gestures, etc.);

— hardware ergonomics;

— software design; and

— processes and procedures.

7 Safe usage

If the user experiences any of the following symptoms, the headset should be immediately removed:

— seizures;

— loss of awareness;

— eye strain;

— twitching;

— involuntary movements;

— altered, blurred; or double vision, or other visual abnormalities;

— dizziness;

— disorientation;

— impaired balance;

— impaired hand-eye coordination;

— excessive sweating;

— increased salivation;

— nausea;

— light-headedness;

— discomfort or pain in the head or eyes; and/or

— drowsiness, fatigue, or any motion sickness-like symptoms.

— skin irritation, typically due to material used in construction of the headset

Exposure symptoms may persist and/or worsen for hours after usage. Even without suffering from VIMS, users may have their coordination and/or visual acuity impacted or suffer from mental and physical fatigue after an AR/VR experience.

Standing VR experiences require a stable platform in order to prevent any possible disconnect between the virtual experience and the real world, for example using VR on a vessel may result in the vessel pitching due to ocean swell in a manner that is not replicated, aligned or coordinated with the virtual experience resulting in a risk of falling, and an increased risk of VIMS.

It is acceptable to have moving or mobile platforms if the movement in the real-world is synced to the same movement in the virtual experience, for example a vehicle simulator that moves in coordination with the virtual experience.

Seated VR experiences may be considered in situations where there is a risk that the experience area, for example the deck of a vessel, has a chance of non-synced movement. However, the risk of VIMS is likely to be increased and, in some cases, may still contain a fall risk. Due caution and consideration should be applied for these particular instances based on a rigorous risk assessment.

7.1 General risk factors to consider with safe usage of AR/VR

Table 2 lists several general safety and risk considerations that should be considered when using both AR and VR HMDs. This table is not exhaustive but outlines the broad type of risks that need to be considered across both device types[19].

Table 2 — Risk factors

Risk	Description
Trip hazards	For both devices ensure the floor space is clear of unnecessary obstructions, fall hazards or trips hazards.
Device boundary settings	Ensure boundary settings are active, with a clear space around the play area, to avoid accidental impact with obstructions, like walls, other people, fans, stairs, balconies, furniture, light fixtures and so forth.
Area contains obstacles	Ensure the use area remains clear. Install a boundary marker, signage or assign a safety person to ensure no people, animals or equipment move into the use space without the user being aware.
Lag between the virtual representation and real-world	Inform the user of any possible lag between the virtual representation and real-world. Lag can occur when handling objects in VR or AR with a real-world aspect. This may include control systems, machinery, surgical equipment and more. If there is any lag the user should be cautious to avoid accidents.
Electrocution hazard	As with any electrical device, do not tamper with or open the headset casing or its peripherals. Do not use the device if any cable is broken or any wires are exposed.
Objects presented in the virtual environment may not be present in actual space	Avoid sitting or standing on objects in the virtual or augmented application.
User distraction or attention loss	AR and VR with passthrough may cause attention distraction. This may cause a hazard when the AR/VR experience includes moving and interacting with objects in the real world.
VIMS	VIMS, often termed cybersickness, may impact users leading to dizziness, nausea and a period of loss of equilibrium. Ensure that the player is aware of this possibility and can exit the experience rapidly and safely if encountering these effects.
General discomfort	Not setting up the HMD correctly can lead to neck discomfort, face pressure and general discomfort. Ensure the HMD is correctly set up for the user. Apply standard WHS and ergonomic principles to HMD use.
Exercise and movement	Many AR and VR experiences involve vigorous movement, or fitness tasks. Before commencing any AR/VR experiences of this nature, ensure that the user is medically fit, as with any fitness program.
Contagious disease or illness	Apply a rigorous cleaning protocol to ensure safe sharing of equipment. Do not share HMDs between users without applying cleaning and sterilizing protocols or using appropriate PPE. Ensure the HMD is thoroughly sterilized and cleaned between each user and after each session. Abide by manufacturers cleaning guidelines for use of chemicals or abrasives. See Annex C for further details.

8 Immersion

8.1 General

Immersion is a sense of belief and presence in an environment[20]. It can include psychological aspects where the task or behaviour that users undertake in the virtual environment creates deep mental involvement. It can also be generated from highly realistic virtual environments that encourage users to suspend belief that they are not in the real world. The concept of immersion is therefore multifaceted, and includes components relating to fidelity, presence, physical experience, mental and physical comfort and flow (see Table 3).

Table 3 — Components of immersion

Fidelity	How closely the virtual environment recreates the real world in terms of environment and tasks. Fidelity aligns to the senses, so generally includes how visual, audio, haptic, and olfactory aspects of a VR task and environment resemble users experience in the real world.
Presence	The user believes or feels they are in the situation or "present"
Physical experience	The degree that equipment in virtual environment or task acts like real equipment
Mental comfort	The experience of cybersickness or other VR related health and safety risks
Flow	Flow refers to a state where users are completely immersed in their activities, losing track of time and space.

8.2 Introduction to safe usage time

VIMS can emerge within the first few minutes of immersion, with longer immersions capable of stimulating greater levels of VIMS and can be felt for over one-hour post use. Eye-hand coordination disturbance has been shown to take up to 6 hours to recover post VR[10].

It is not practical to give guidance on the maximum immersion time due to people's individual reactions and the changing nature of technology. However, a person's reaction to the equipment should be regularly reviewed and breaks taken as individually necessary.

8.3 Potential risks around immersion time

There are potential risks with AR/VR use that can increase with immersion time. Risks include:

— eye soreness;

— trouble focusing;

— blurred vision;

— impaired hand-eye coordination;

— reduced depth perception;

— decreased reaction time;

— loss of balance; and

— fatigue.

Other risks around the use of VR include:

— prolonged nausea;

— impaired posture;

— repetitive strain injuries;

— infections related to hygiene/sterilization issues;

— falls risk;

— physical fatigue (eg: arm and leg movements in VR and large screens); and

— insomnia.

8.4 Content that minimizes immersion issues

Minimizing immersion issues often results in a trade-off since factors that decrease VIMS also decrease immersion (see Table 4 for relevant information).

Table 4 — Content that alter immersion issues

Content that increases immersion issues	Content that minimizes immersion issues
Vection (the illusion of motion whilst stationary): movement in VR does not correspond with actual movement.	Teleporting or flying causes less of a mismatch between systems of sight and balance[10]).
Large field of view: (FoV)	Reducing field of view may reduce vection[10]
Extreme eye-gaze requirements: this has been associated with heterophoria (where the eyes point in two different directions at rest).	Content that does not require extreme eye-gaze requirements[10]. Adjusting the interpupillary distance on headsets
Realism	Decreasing realism can decrease cybersickness[10].
Poor depth of field (DoF)	A range of vision where the image is acceptably sharp. This helps overcome vision disturbance, nausea, and disorientation[10].
Dark environments: Can cause fatigue and reduced concentration and sleepiness[20]	Content that provides light environments
Stereovision	Monovision

8.5 User training

Various user training and deliberate actions can assist in mitigating immersion issues. These actions include habitation, ocular motor exercises, developing familiarity with equipment and proper fitting of equipment (see Table 5 for additional suggestions).

Table 5 — Training and management of immersion issues

Immersion issue	Management
Visually induced motion sickness (VIMS)	— Habituation: Routinely using AR/VR exposure at least weekly (habituation). Periods between exposure is less important than number of exposures[10] — Remove from VR and rest until symptoms pass[20] — Familiarity with adjustment mechanisms[10] — If the user wears glasses these should be worn in VR[10,20]. — If a person is experiencing respiratory ailments, eye injuries or disease, emotional distress, digestive issues, significant sleep loss, or hangover effects use of VR equipment should be avoided[10]. — Operating heavy machinery or driving a vehicle should be avoided until VR-related symptoms have passed[10]
Eye strain	— Ocular motor exercises prior to using VR[10] — Familiarity with adjustment mechanisms[10] — If the user wears glasses, these should be worn in VR to reduce double images[20]
Physical strains	— Headsets well fitted, weighted and adjusted[20]
Physical force or injury	— Physical environment should be cleared of obstructions, cords and cables cleared or controlled[20] — The use of an observer is highly recommended[20]
Medical conditions (e.g. epilepsy, pregnancy)	— Consult a medical practitioner before use[20]

8.6 Factors of relevance when determining immersion time by industry and sector

The following factors should be included in the determination of immersion time:

a) **Prolonged use:** Prolonged use of AR and VR has been shown to cause short term and long-term issues that can affect a person's ability to operate heavy machinery and drive vehicles[10,20]. There is currently minimal research or data in this area.

b) **Confronting content:** VR should be used with care, as highly stressful and complex situations can cause traumatic reactions and psychological distress. Confronting content requires adequate user preparation and caution[21].

c) **Physical environment:** Care should be given to provide adequate space for AR/VR use and area cleared of obstructions. The use of an observer can assist with safety for the user[20].

d) **Contamination risk**: Cleaning and sterilization should follow manufacture and health Safety Procedures recommendations[20]. See Annex C.

e) **Mental fatigue and cognitive load:** Cognitive Load can be classified as:

   — Intrinsic: Inherent level of difficulty associated with a specific instructional topic

   — Germane: Devoted to the processing, construction, and automation of schemas:

   — Extraneous: Generated by the way information is presented to learners and is under the control of instructional designers.

   This is increased by unnecessary information complexity and can interfere with new learning[22]. The extraneous cognitive effort placed on the user should be as low as possible. The AR/VR experience and equipment should not impede a user in anyway by distracting them from their core task or objective. Learning is enhanced if complex tasks are broken down into the smallest practical components.

9 Reporting requirements

9.1 General

Emerging AR and VR hardware devices and expanding use of these technologies in commercial and home usage contexts necessitate AR/VR standards based on current knowledge. However, understanding of the considerations and factors affecting safe immersion, set up, and usage continues to evolve, and therefore, the safe use and effectiveness of AR and VR technologies will be informed by consistent data collection, and subsequent analysis and reporting of this data. Shared reporting of AR and/or VR induced symptoms and effects will ultimately lead to clearer standards and usage recommendations. To enable this, the following minimum AR/VR set up and usage data reporting requirements are recommended in all commercial and workplace usage settings, noting that this is a recommendation only, and does not replace or circumvent WHS and/or product law incident reporting requirements.

9.2 Reporting of hardware and equipment

AR/VR technologies, including but not limited to HMDs, visors, glasses/goggles, mobile phones and tablets, may impact on the safe and effective experience of users. Details on the specific hardware and associated peripheral equipment used to create an AR/VR experience, including model numbers and configuration details, are recommended. This reporting may include the following details where applicable:

— PC/laptop specifications including model, processor, and memory (RAM + GPU);

— mobile device (phone/tablet) model, memory;

— AR/VR head mounted display (HMD), glasses/goggles, or visor model;

— peripheral and/or input devices used (including specific model details), such as joysticks, controllers, haptic devices, motion platforms, and treadmills.

9.3 Reporting of AR/VR device and content software

Reporting of software is recommended to include any AR/VR device operating system information, as well as details on relevant content delivery software for the AR/VR experience. Details may include (where applicable):

— PC/laptop or mobile device (e.g. phone/tablet) operating system, including version number;

— AR/VR head mounted display (HMD), glasses/goggles, or visor vendor software and firmware; and

— AR/VR content software such as that used for development and deployment may also be recorded.

9.4 Reporting of AR/VR activity

Reporting of AR/VR activities is recommended to capture key aspects of the experience that impact on user experience including, but not limited to:

— AR/VR activity type, including details such as movement (e.g. stationary viewing versus user-controlled walking/running in the virtual environment), user perspective (e.g. 1st person/3rd person), teleportation, hand-tracked object manipulation, etc.

— AR/VR activity duration including:

  — duration (number of days/minutes per day) of tutorial/familiarisation activities performed while wearing AR/VR HMDs; and

  — duration (number of days/minutes per day) of activity performed while wearing AR/VR HMDs.

9.5 Reporting of data for individual users

The use of AR/VR technology may be experienced differently by individuals based on individual characteristics. Reporting of AR/VR usage (and incidents) should capture general demographic characteristics of users to facilitate identification of any patterns and trends affecting usage. These characteristics may include age, gender, nationality and/or cultural background and pre-existing medical conditions (e.g. vision issues such as colour blindness, lack of stereoscopic vision, less than 20/20 vision; health issues such as heart conditions, epilepsy, motion sickness susceptibility).

AR/VR hardware adjustment (e.g. adjustment of interocular distance) may be recommended by manufacturers to accommodate individual user physical characteristics. Capturing information on whether any adjustments for individual users were made is recommended.

9.6 Reporting of screening and/or exclusion criteria for AR/VR usage

The use of AR/VR technology may not be suitable for all users based on pre-existing conditions or following manufacturer recommendations. Recording of data on any criteria or process used to determine if an individual user should not participate in the AR/VR experience is recommended.

9.7 Reporting of incidents

Specific incidents, or incidents arising from prolonged exposure may arise with the use of AR/VR technology. A standard process for capturing short-term and long-term AR/VR use incidents, particularly in commercial and/or workplace environments, is recommended. AR/VR use incident reporting includes general AR/VR use data together with any specific physical symptoms related to the incident.

Two forms are included in this document to facilitate reporting of AR/VR usage and incidents:

— Annex A includes Form 1: AR/VR Usage: Data Collection Form

— Annex B includes Form 2: AR/VR Usage: Incident Reporting Form

10 Consideration of ethical issues in AR/VR

10.1 General

AR and VR technologies may raise several ethical issues that should be considered before their use. In many cases, technical and policy solutions are still evolving for addressing these issues. The long-term ramifications of these ethical issues should be understood. This clause presents the most pressing ethical issues which should be understood in the safe set-up and usage of AR/VR.

10.2 Privacy and user data

Sensitive data about the user, their actions and surroundings are required for AR/VR devices to function properly and to run AR and VR experiences seamlessly and safely. VR usage provides unique recordings of body language that may be used to profile users[1]. Collecting this sensitive data could allow new ways of profiling users. Moreover, access to biometric data may enable the identification of health-related issues or the extraction of information such as iris scans, face geometry and voiceprints that are used for authentication processes. Anonymizing and deidentifying AR/VR tracking data alone is not a sufficient mitigation strategy, since, (e.g. access to VR tracking data made it possible to identify a user out of a pool of 511 people with an accuracy of 95.3 %)[23].

Privacy laws are generally trailing emerging technologies. Some AR/VR data falls under existing privacy laws and regulations. There are no harmonized international legislations. However, data use is often regulated at the state level. The degree to which some AR/VR data are covered by existing laws is still evolving in courts and legislatures which can leave users and developers in regulatory uncertainty[24].

One approach to tackle the regulatory uncertainty is the use of voluntary practices to secure user privacy. For example, the XR safety initiative (XRSI) has developed an XR privacy and safety framework that aims

to help organisations define their privacy goals, identify privacy risks, and optimise personal and sensitive information while limiting privacy violations[25]. Other multi-stakeholder fora are also looking to address these issues.

10.3 Inclusion and access

Some individuals may not be able to fully participate in activities involving the use of AR/VR technologies. Examples of reasons limiting an individual's ability to participate include:

— motor and physical disabilities;

— low vision and other sensory deficits;

— medical conditions such as epilepsy and cognitive impairments; and

— susceptibility to VIMS.

While any inequity in access is undesirable, this is of particular concern where individuals may be disadvantaged through inability to participate, such as in educational and workplace settings. To ensure equity, alternative training, learning and engagement opportunities should be offered to these individuals whenever possible.

Reducing inclusion and access issues involves the entire industry and developers have a key role to play. Where possible, people with disabilities should be directly involved in the co-design of AR/VR technologies. Resources and guidelines are available that developers can consult to make their products more accessible and equitable. For example, Meta[1)] provides a detailed accessibility design documentation for developers[26], the XR Association (XRA) has a developer guide for accessibility and inclusive design in immersive experiences[6], and the initiative XR Access provides a collection of different resources and guidelines to build safe and inclusive communities[27].

10.4 Children and vulnerable populations

Broadly speaking, physiological and psychological ethical concerns can be distinguished. While a number of recent studies did not raise concerns related to visuo-motor functions in children after VR use[3,5], it is important to point out that there are currently no mid- to long-term studies on VR's impact on the children's visual development. Those studies will need to be cognisant of the speed of technological advancement impacting the efficacy/usefulness of mid to long terms studies. A further issue is that common headsets are designed for adult users, and these designs may add additional strain on children because of their smaller heads and smaller interpupillary distances.

Psychological concerns for children and vulnerable populations include the potential for traumas and negative mental health impacts due to exposure to inappropriate content, abuse and harassment. These concerns are similar to those raised for other digital services, but the potential for negative impact may be more substantial with VR because the technology is more immersive and elicits feelings of presence and 'realness'. There are also reports that VR can induce false memories in children[6] and a higher tendency to believe that impossible events are possible after seeing them in VR compared to traditional videos[7]. These findings allude to children's potential difficulties in discerning what is real and unreal. This is not as much of a concern when using AR technology as the experience is less immersive.

The paucity of research leaves many unanswered questions regarding the effects of VR on children and there is no consensus on when children should be allowed to use AR/VR. VR headset manufacturers design headsets for use by adults and indicate that these devices should not be used by children under a specified age (e.g. currently a minimum of 10 years of age).

1) Meta is the trade name of Meta Platforms. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC.

Laws and policymakers are still catching up with making AR/VR a safer place for children, but some safeguards can be put in place now:

— if parents, caregivers or teachers decide to offer VR experiences to children, the sessions should be supervised to ensure age-appropriate content, and the exposure should be limited to appropriate sessions;

— companies should design VR experiences with effective safety mechanisms to minimize harm to children. This can include accurate age verification, content warnings and the ability to block bad actors [see 9]. Many companies have been addressing these needs and should continue to do so.

10.5 Online bullying and harassment

Bullying, harassment and groping are well-described issues in social VR experiences[10]. For example, a survey of over 600 regular VR users found that 49 % of women experienced at least one instance of sexual harassment, and 30 % of the male participants encountered racist or homophobic comments[11]. Companies are working on solutions to address these issues. For example, personal boundaries such as mandatory distances between people's digital avatars[13] aim to prevent anyone from invading the avatar's personal space. Such personal boundaries aim to prevent anyone from invading the avatar's personal space. This requires participants to identify and turn off privacy features they find undesirable, thereby demonstrating functions to the user. Starting points to learn how to create safe, inclusive and respectful immersive VR experiences are[10] and[14].

10.6 Societal impact

The societal impact of extended AR/VR use is a matter of debate and speculation. There are many positive social impacts in areas including career training, empathy training, healthcare use in physical therapy and connecting people. There are, however, concerns around increased risks of social isolation and escapism, desensitization and losing touch with the real world, among others.[15] There are also questions related to issues such as the management of virtual crimes and the protection of an individual identity in virtual worlds. Some initiatives are emerging to provide guidance and recommendations on some of these questions.[16]

Annex A
(Informative)

Form 1: AR/VR Usage: Data collection form

FORM 1: AR/VR USAGE: DATA COLLECTION FORM		
Usage Description (*provide details of AR/VR usage*):		**Form completed by:** ---------- **Date form completed:** ---------- **Contact email:** ----------
AR/VR Headset details (*including model*):		
Hardware/Equipment (*if applicable*):	☐ Laptop/PC	☐ Mobile/Tablet Device
Model (*including processor, memory, etc*):		
Operating System (including version):		
Peripheral Devices (tick all that apply):	☐ motion trackers/controllers ☐ joysticks ☐ track pads ☐ sensing gloves	☐ device control buttons ☐ haptic feedback systems ☐ treadmills ☐ body suits ☐ other
AR/VR ACTIVITY DETAILS		
Type of AR/VR activity:		
Duration of <u>tutorial/familiarisation</u> activities performed while wearing AR/VR: Days: _____ Time (mins) per day: _____		**Duration of <u>activity performed</u> while wearing AR/VR:** Days: _____ Time (mins) per day: _____
General characteristics of AR/VR users:	Number of users:_____ Average Age: _____	Proportion Male: _____ Proportion Female: _____ Proportion Other: _____
Were users excluded for any reason? ☐ Yes ☐ No *If yes, please select all that apply from below:* Vision issues: ☐ Eyesight ☐ Colour blindness ☐ Stereoscopic ☐ vision Other vision issue Health issues: ☐ Epilepsy ☐ Heart condition ☐ Motion sickness ☐ susceptibility Other: _____		
Was the AR/VR technology adjusted (eg. interoccular distance) for individual users? ☐ Yes ☐ No		
INCIDENT REPORTING		

Did any users stop using the AR/VR technology before the end of the activity? ☐ Yes ☐ No If yes, how many: _____ *Complete the AR/VR Usage Incident Reporting Form for each affected user.*		
Did any users report discomfort during AR/VR activities (*tick all that apply*):	☐ Nausea ☐ Headache ☐ Dizziness ☐ Vision problems	☐ Vomiting ☐ Confusion/Disorientation ☐ Balance issues ☐ Other _____
Optional: Complete the AR/VR Usage Incident Reporting Form for each affected user.		

Annex B
(Informative)

Form 2: AR/VR Usage: Incident reporting form

FORM 2: AR/VR USAGE: INCIDENT REPORTING FORM (PLEASE COMPLETE ONE PER INCIDENT)		
Usage Description (*provide details of AR/VR usage*):		**Form completed by:** --- **Date form completed:** --- **Contact email:** ---
AR/VR Headset details (including model):		
Hardware/Equipment (*if applicable*):	☐ Laptop/PC	☐ Mobile/Tablet Device
Model (including processor, memory, etc):		
Operating System (including version):		
Peripheral Devices (tick all that apply):	☐ motion trackers/controllers ☐ joysticks ☐ track pads ☐ sensing gloves	☐ device control buttons ☐ haptic feedback systems ☐ treadmills ☐ body suits ☐ other
AR/VR ACTIVITY AND ADVERSE EVENT DETAILS		
Type of AR/VR activity:		
Location of activity:		
Duration of tutorial/familiarisation activities performed while wearing AR/VR: Days: _____ Time (mins) per day: _____	**Duration of activity performed while wearing AR/VR:** Days: _____ Time (mins) per day: _____	**Duration of time wearing AR/VR before adverse event:** Days: _____ Time (mins) per day: _____
Details of affected AR/VR user:	Age: _____ Gender: ☐ Male ☐ Female ☐ Other Nationality/Cultural Background: _____	
Does the user have any of the following underlying health conditions (*tick all that apply*):	Vision issues: ☐ Eyesight ☐ Colour blindness ☐ Stereoscopic vision ☐ Other: _____	Health issues: ☐ Epilepsy ☐ Heart condition ☐ Motion sickness susceptibility ☐ Other: _____