Technical Brief

Considerations for sustained AR/VR use by LEAs

DISSEMINATION LEVEL: PUBLIC

PARTNER

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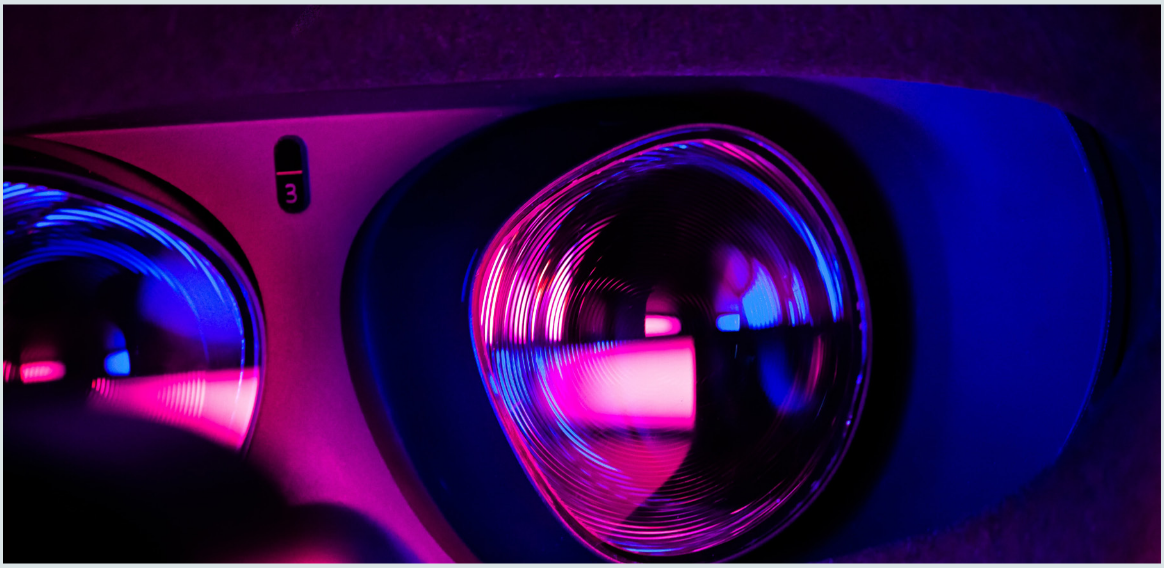
This document has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 883293. The content of this document represents the view of the authors only and is their sole responsability. The European Commission does not accept any responsabilty for any use that may be made of the information it contains.



1 Virtual immersive environments

Virtual immersive environments are increasingly considered by industry and scientists as technologies that could improve current computer-based tasks. Possibilities demonstrated by virtual reality (VR), such as remote working with immersive analysis tools and with an increasing sense of presence, have led to the uptake of this new and remote working environment. But immersive technologies, such as augmented reality and virtual reality (AR/VR), can bring with them negative or unknown impacts on the user. This technical brief provides an overview of the different impacts of immersive technology on health, cognition and well-being of human beings and how to use AR/VR sustainably for LEAs' work. More detailed information on these subjects can be found in the INFINITY project deliverables 2.1 and 3.1.

1.1 Immersive technologies

New technologies, such as **immersive technologies** are becoming more and more popular, for fun and gaming but also in the working world as they give the opportunity to help and facilitate demanding work processes. Immersive technologies aim to achieve immersion and interaction with digital content by introducing peripherals and multimodal interfaces for interaction, navigation, and perception in 3 dimensions (with mouse, joystick, headset, glasses, etc.). Different technologies exist such as **Augmented Reality** (AR) and **Virtual Reality** (VR).

These different technologies are grouped under the Mixed Reality (MR) denomination. MR includes all kinds of technologies which bring **fusion** between the **virtual** environment and the **real** environment. But immersive technologies can bring different levels of fusion, and to describe it, Milgram and Kishino[1] developed the theory of the virtuality continuum.

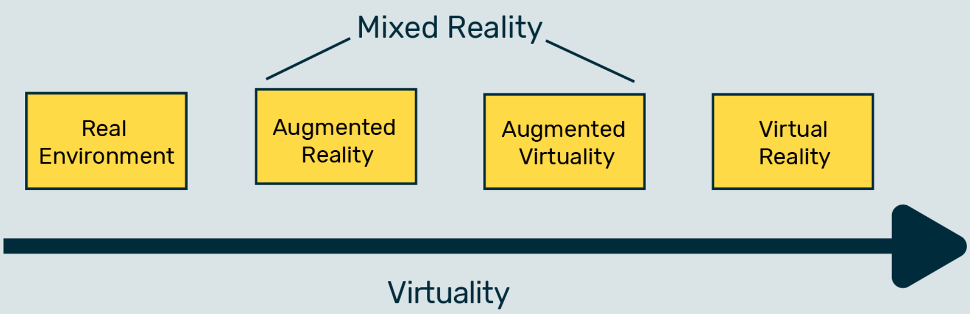


Figure 1: Virtuality continuum, described by Milgram & Kishino

The first level starts in the **real environment**, i.e., without any virtuality. The next level, **Augmented Reality**, concerns the real environment with input of virtuality in it. Augmented reality glasses, for instance, overlay virtual content (information, objects) to the real environment. Technologies in AR are about the integration of simulated elements in the reality to enrich it and not to replace reality. It is defined as the semantic and spatial association of real and virtual computer-produced objects (D2.1).

After this level we move into the replacement of reality by virtuality. This level is called **augmented virtuality**, it corresponds to the input of real-world content in a virtual environment, such as the vision of a real keyboard in a totally virtual environment, in a headset. The last level is the **virtual environment,** defining world in total virtuality. Virtual Reality devices isolate the user and display synthetic environment to immerse the users, such as CAVE or headsets.

These new virtual reality technologies allow for new interaction between humans and systems (VR with headset or AR with glasses and with joystick, movement, and others). In the total virtuality the sense of presence and the necessity of **avatars** become important. This refers to the virtual representation of the self in the virtual world, which can be anthropomorphic, resembling or not at all, depending on the needs of realism and immersion of the environment.

Even if the virtual environment brings the possibility of freeing oneself from certain physical limits, researchers[2,3] emphasize the importance of the body and interaction between gesture and virtual interfaces. This can affect immersion, and while these new technologies are supposed to help workers with this immersion, to be more involved in work, these new interactions and technologies can still bring risks for the health and efficiency at work that need to be studied.

1.2 Presence and immersion

Virtual environments can give users a feeling of **presence** without being in an environment. and support remote work. A common workspace allows team members to collaborate more easily by joining their effort to align their activity in a “transparent” manner and without interruption.[4] Immersive collaborative environments for work can enhance team performance, by providing a shared environment and a technology more adapted to visualizing and interacting with complex data, alone or in team.[5,6] Immersion and presence are important in this kind of environment because they can help users feel the “flow”, the equilibrium between resources and challenges at work. But an immersive environment does not provide presence and immersion by itself.

Presence is defined as a “strong illusion of being in place in spite of the sure knowledge that you are not there”.[7] It is a state in which the user experiences the environment exposed as real. Three components define the presence (D2.1, chapter 2.2):

- **physical presence:** feeling of being present in the mediated environment;
- **self-presence**: feeling connected to the virtual body, emotion, and identity;
- **social presence:** perception of the other in the virtual environment and feeling they are “here” with the user.

It can be supported by the perception that virtual objects are real, by the possibility of representing one’s body in relation to the environment, carrying out spatialized actions, and the access to a large communication tool for communicating intelligence, intention and access to sensory impression.[8] The experience of presence by users can depend on two things:

- **User factors**: Level of perceived interactivity, task involvement, the user’s trust in the environment. Furthermore, they can be impacted by usability, learnability, guessability and a sense of comfort,[9] i.e., the ease of navigation, the ability to perform action, selection, and manipulation; and the ability of the users to guess how to utilize the device and how it will react to an action (coherence). User presence is improved when they are not distracted by difficulties in interacting and understanding the environment.
- **Tools factors**: Level of interactivity, stereoscopic vision, sensory richness, latency, type of content. This factor concerns immersion. Immersion is a way to categorise a virtual environment, each category of virtual environment has a level of immersion, depending in the quantity and quality of interaction. Immersion is measured in function of the level and the quality of control of the sensorial modality made by the system interfaces.

Virtual Reality is designed to bring a high level of immersion, due to the virtual continuity, but the presence cannot be at a high level because of user factors. Vice-versa, a user can be confronted by a tool with a low level of immersion, such as a book, but feel a high level of presence, because of user factors. If the tools factors can be manipulated and the level predicted, the impact for user factors are less clear. They can be manipulated but are not predictable because they depend on the level of knowledge of each user, previous experience, involvement in the project, for example.

The literature provides some initial points of attention for the development of a sustainable virtual environment, However, the usefulness and value of virtual environments for work still needs to be evaluated.

2 State of the art in using AR/VR for LEAs

Because VR has the prospect to replace aspects of the current working environment, the risks in using these immersive technologies are increasingly considered. One of the subject studies is about interaction and interfaces. While the debate is still ongoing, different types of ergonomic and cognitive problems using this immersive technology have already been identified.

2.1 Ergonomic issues

The literature mentions numerous factors impacting health and cognition of immersive technologies users, especially for Virtual Reality. For instance, VR can cause side effects[10] like cybersickness and impact on mental workload.

Cybersickness: A feeling of sickness and experiencing symptoms when using VR, for example, visual fatigue, headache, pallor, sweating, dry mouth, full stomach, disorientation, nausea, and tiredness.[10,11,12] Research is still ongoing, and there is not yet a consensus on the mechanism, but this phenomenon finds explanation in theory: "*passive movement creates a mismatch between information relating to orientation and movement supplied by the visual and the vestibular systems, and it is this mismatch that induces feelings of nausea*".[13] When a virtual environment induces a lot of vectors (multiple head movement, mismatch between visual and kinesthesis, walking), symptoms will occur.

Numerous factors can be found to impact on cybersickness, such as the duration of exposure to the virtual environment; with more exposure leading to increased risk of feeling cybersickness.[14] Locomotion and visual feedback are also crucial for cybersickness[15]. More research is required on this subject to better understand and avoid cybersickness, but, a recent study shows that 15% of participants in experiments with VR are susceptible to drop out because of cybersickness.[16]

Mental workload: It can be impacted when using VR for working, and it can impact the performance to the task. It is defined as limited resources available for mental processes, such as working and its sub mental processes (filter information, evaluate it, share it, build situation awareness). These resources are allocated across different tasks.[17,18] But, because the resources are limited, a worker can find themselves overloaded quickly and easily; negatively impacting their cognitive processes for working performance (quality and time completion).[19] In general, the overload can be induced by difficulties linked to the following.

» 1) Task and environmental factor (noise, technologies too complicated for the user, amount of information),

» 2) Operator's characteristics (motivational state, experience as training on using the technology), and

» 3) Response and feedback (errors detection, objectives, feedback or not).

In relation to using VR for working, the results didn't show consensus about the impact. Some of them found positive impact and others negative impact. A finding currently being widely accepted is that a material/tool that is too complicated to be used and understood induces a mental overload, but that the VR tool isn't, by itself, more cognitively demanding than using a PC. VR and its spatialization possibilities can even be a way to reduce mental workload for task needing spatialization cognitive resources.[20,21,22,2324] And it is important to notice that when mental workload is high it can decrease with familiarity and practice.[25]

Using immersive virtual environments, especially VR, induces real ergonomic risks, and two ways of dealing with these problems can be initiated and co-exist:

- 1) Physiological tracking when using VR environment in working, to be able to see from the first symptoms the arrival of side effects, even before the user is aware of them, and to suggest stopping it.
- 2) Have a user-centric approach to construct the environment, interaction and interfaces, to avoid being too far from what users are accustomed and to be easily understandable.

2.2 Affect issues

While we have seen above that VR can impact physiological response when being used for working tasks, we will take a look now on the affect response impacting work performance, such as stress and motivation.

Stress: Stress is defined as a "state of uncertainty about what needs to be done to safeguard physical, mental or social well-being."[26] It can be a side effect of using VR at work, and it is known to be a significant issue for well-being, that can lead, in the long term, to depressive symptoms, hypertension and even diabetes.[27,28] Stress can be induced by the technology being used. This is called technostress.[29] But stress can also be induced by noise (disturbing conversation in VR or interfaces noises), the task difficulty (large amount of data without the knowledge of how to deal with it in the immersive environment) and time pressure (loss of the sense of time in VR and difficulty to self-regulate the activity). The last two factors are also impacting the mental workload, which is important for working efficiency as we have previously shown.

Motivation: It is recognized to have an impact on cognitive process, and the environment can modify the motivation of the user. The cognitive process that can be impacted is involved in the working activities of collaboration or problem solving, made by the LEAs, such as starting the activity timely, continue the activity, self-evaluate progress, etc. Some researchers recognize a high level of immersion to have a positive impact on motivation[30]. In the theory of a continuum of motivation, Deci and Ryan[31] assume that motivation can evolve and change from the least self-determined (extrinsic motivation) to the most self-determined motivation (intrinsic motivation). Thus, users involved in intrinsic motivation will have intrinsic regulations, their activities result from their own choices, values and representations.[31] A user, driven by intrinsic motivation, will perform a task because the task itself is a source of gratification.[31] The user will be involved and explore the activity as much as possible by taking on challenges. Conversely, literature finds that a user with extrinsic motivation is engaged in an activity because of an external consequence, in order to obtain a reward or avoid reprimand for example. Individuals with so-called intrinsic (or autonomous) motivation thus have more perseverance than individuals in a situation of extrinsic (controlled) motivation. Virtual reality is a tool bringing by itself positive extrinsic motivation (use it for fun, because it is new) or negative extrinsic motivation (avoid using VR because of technostress). But VR can bring intrinsic motivation by furnishing tools helping to be more efficient on working task and increasing the involvement in the activity. It can also bring intrinsic motivation by being less disruptive and taking advantage of tools that facilitate the visualisation and analysis of large amounts of data.

3 Sustainable use of AR/VR for LEAs

As we have shown above, immersive technologies can bring positive impact on users but also negative impact, on health, cognition, and well-being. To ensure a sustainable use of these technologies, the literature review allows to extract some guidelines to reduce ergonomic risk and cognitive impact.

3.1 Reducing ergonomic risk

When dealing with **cybersickness**, muscle fatigue and visual fatigue, some guidelines, extracted from the literature review and extrapolation of the results, may propose ways to build sustainable use of immersive environments for LEAs. To reduce the appearance of symptoms of cybersickness, a limited use of VR is recommended, with short durations of applications (30 min), followed by breaks. Also, playing 3D video games or using immersive technologies before using it for working can be a good way to acclimate to movements on screens. Because some previous natural predispositions are known to lead to more cybersickness, identifying them, by administrating a questionnaire before the session, can help to adapt the user's exposition to VR, for example, using the Visual Induces Motion Sickness Questionnaire.[32]

In addition, as a headset's interpupillary (IPD) range of adjustment mismatch can induce cybersickness, is recommended to use headsets with widest lense distance tuning. With regard to cybersickness' technical impact, a slow update rate has negative impact. Therefore, headsets with the highest update rate possible should be preferred. Haptic feedback (vibration) related to movement could alleviate cybersickness if it is relevant and timely to the action. Spatial congruence is also important and creating audio-visual matching can help generate coherent movement perception. This coherent movement perception is also achieved by avoiding uncontrolled movements and using low locomotion speed, or by using teleportation with spatial indication references. But the best solution is to offer these two options and allow users to choose the locomotion technique. Concerning posture to work, several can be used: sitting, standing, and walking, but sitting it is considered to be the most advantageous one for VR use at work. Visual fatigue, impacting cybersickness, can be reduced by avoiding fast-moving objects and ambiguous occlusion, by reducing the number of 3D objects for example. Muscle fatigue can also be avoided by limiting head rotation, interaction requiring too wide gesture or also building a session with alternating standing and sitting positions.

Understanding **mental workload**, and avoiding mental overload is about reduction of time pressure, by giving more time to fulfil tasks in VR than PC and giving deadlines for tasks (this guideline is true also for non-virtual environments). Also, using headsets increases the temperature in a room, and warmer conditions can influence mental workload. A room with a temperature cooler than usual should be considered. But the more important thing is to reduce the tasks' difficulty. For that the system must be designed with the following in mind: avoid multi-tasking (no incongruent emails during other tasks, fewer notifications); to interact with easy control and access (no requiring unnecessary working memory solicitations); to use spatialized information and spatialized interaction only if the tasks require it; and to provide information on how users fulfil the tasks (feedback, visual cues, virtual assistant).

3.2 Reducing cognitive impact

When considering **stress** in VR, the first thing that needs to be addressed is technostress. To avoid technostress, we propose training and familiarisation with the system, sufficiently long to allow the user to learn how to use it and prevent techno-complexity. Also, to manage time in VR it is important to reduce time pressure feelings (with timer, clock and automatic reminder or alarm). Concerning pressure, filtering the noises and all sources of sounds and audio feedback has to be automatic and has to be controllable optionally by users. Dynamic adaptation of the system to the user or a helping agent can be a response to task difficulty in VR. Because stress can appear, the system must propose a calm configuration, to help the user to take a break, relax, or control exposure to distressing material by applying filter on images and videos.

Understanding **motivational process** may help to build a virtual environment satisfying the motivational need, favouring positive affect, and promoting usability, using the motivational theory to

- » 1) Build a system supporting autonomy and representation of self-identity. For that customization tools are important for the avatar but also for the environment (moved object, selected and moved tool, self-organization of the data/documents);
- » 2) Propose an optimal challenge with an environment. Including guidance for beginners or non-specialists but also allow experts to create or use shortcuts to expedite their task;
- » 3) Provide timely feedback about the action of the system (downloading, done, etc.) and about the progress of the tasks and subtasks to help self-regulation of the users' activity (with a dashboard);
- » 4) Facilitate the interaction and the representation of the role by providing: a large field of view, audio in groups or one to one; a list of connected users, role and access of the users; the users' positions on the map and a way to send emails to manage the activity;

- 5) Facilitate the sharing of information between users to be able to share their opinion by providing multiple screens to display uploaded document, customizable in organisation and number (enough for everybody); and provide audio zones to facilitate communication on one subject, without being disturbed by other conversations and unrelated topics;
- 6) Induce positive emotions by providing hedonic quality and design efforts to support workflow as: providing tool supporting non-linear analysis as snapshots, combining navigation style chosen by the users (egocentric or non-egocentric), respecting ergonomic criteria (as compatibility, guidance, explicit control, significances of codes and behaviour, adaptability, consistency and error management).

4 Future challenges and opportunities

The literature review showed that numerous guidelines have been developed and will further evolve with advances in these areas of research. For the moment, we propose to consider the guidelines based on several studies[33,34,35,36] addressing sustainable immersive environment use for LEAs workers:

The following guidelines should be applied during the **conception and design** of the immersive environment (IE) for a healthy, safe and performant user experience:

- Most of the tasks that users have to do in IE have to be completed within 20 minutes.
- A familiarisation phase is necessary to provide to the user and overview of fundamental interaction and system feedback.
- Limit stereoscopy display to the tasks requiring depth cues and limit movement.
- If locomotion is necessary prefer teleportation with orientation guides.
- Allow customization by the users with the environment: avatar, interface, interactions.
- A monitoring toolkit should be used, with questionnaire and physiological measures for detection of side effects.
- Help users to feel less stressed by providing calming virtual environment with trees, day light and relaxing music.

The next guidelines have to be followed by the **employers** of the users of the INFINITY environment for a healthy, safe and performant user experience:

- Provide training for users about hardware and software platforms, to reduce technostress, habituation, desensitization for the riskiest population and promote the right amount of mental workload.
- Adapt tasks to virtual environment constraints (sequence task to respect the maximum time to spend in VR).
- Inform users of the VR side effects and ask them to fill in anonymous information sheets.
- Use the monitoring toolkit to detect side effects and be able to establish a use benefit/risk ratio.

The last guidelines have to be followed by the **user of the environment** for a healthy, safe and performant user experience:

- If symptoms appear (cybersickness, fatigue, stress or fail at tasks) stop using the virtual environment.
- After using the virtual environment, 20 min maximum, take a break and relax by micro-napping, walking, drinking water, or listening to music.
- User aged 40 or more, or with pathologies/particularities (eye diseases, overweight, neuroatypical, epilepsy, balance issues, muscle issues, cognitive particularities), consider yourself as potentially more sensitive to side effects and therefore be extra vigilant about the appearance of symptoms.

The current use of headsets and virtual environment will most likely induce side effects, even by following these guidelines. A ratio risk/benefits must be established when we introduce an immersive environment, and a user centric approach must be respected.

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