Ref. Ares(2025)7011512 - 29/08/2025

Funded by the European Union

PRESENCE

A toolset for hyper-realistic and XR-based human-human and human-machine interactions, PRESENCE

Grant Agreement nº 101135025

HE Call identifier: HORIZON-CL4-2023-HUMAN-01-CNECT
Topic: HORIZON-CL4-2023-HUMAN-01-21

Type of action: HORIZON Research and Innovation Actions

D1.2: Human-centred Development Phase II – Intermediate User Testing, Presence Evaluation, Ethics, Trust & Privacy

DISSEMINATION LEVEL

☒	**PU**	**Public**
☐	SEN	Confidential, only for members of the consortium (including the Commission Services)

Grant Agreement nº:	Project Acronym:	Project title:
101135025	PRESENCE	A toolset for hyper-realistic and XR-based human-human and human-machine interactions

Lead Beneficiary:	Document version:
IMEC	V1.0

Work package:
WP1 – Human Centred Development

Deliverable title:
D1.2 Human-centred Development Phase II - Intermediate User Testing, Presence Evaluation, Ethics, Trust & Privacy

Start date of the project:	Contractual delivery date:	Actual delivery date:
1st of January 2024	30th of June 2025	29th of August 2025

Editor(s):
Elias Blanckaert (IMEC), Louise Hallström (IMEC), Iris Jennes (IMEC)

LIST OF CONTRIBUTORS

PARTNER	CONTRIBUTOR
IMEC	Louise Hallström, Elias Blanckaert, Iris Jennes
UHAM	Fariba Mostajeran
UB	Ana Zappa, Michael Wiesing
JRS	Werner Bailer
I2CAT	Diego González Morin
SENSEGLOVE	Gijs den Butter

LIST OF REVIEWERS

PARTNER	REVIEWER/S
UHAM	Frank Steinicke
I2CAT	Sergi Fernandez Langa

CHANGE HISTORY

VERSION	DATE	PARTNERS	DESCRIPTION/COMMENTS
V0.1	22 – 11 – 2024	IMEC	First draft
V0.2	24 – 04 – 2025	All	Updated structure and adjustments
V0.3	16-06-2025	IMEC	Send out for review
V0.4	27-06-2025	All	Consolidated version based on review
V1.0	18-08-2025	IMEC, I2CAT	Final formatting, minor editions, addition of the EEA report; submission to the EC through the Participant Portal

Executive summary

The primary aim of Work Package (WP) 1 is to lead the human-centred development process that underpins the entire PRESENCE project. WP1 provides the methodological framework and empirical foundation for evaluating and refining the technologies developed in WP2 (Holoportation), WP3 (Haptics), and WP4 (Intelligent Virtual Humans). By conducting iterative user testing, presence evaluations, and requirement validation, WP1 ensures that all technological components are aligned with end-user needs, ethical standards, and contextual constraints. This feedback directly informs the integration and demonstration activities in WP5. Deliverable D1.2 presents an intermediate report on WP1 activities, building on the outcomes of D1.1. It includes insights from usability and user experience (UX) testing, the activities related to trustworthiness and robustness of AI, the first iteration of presence evaluation, and a validation of requirements across the four use case (UC) domains: (i) Professional Collaboration, (ii) Manufacturing Training, (iii) Health (Pain Relief), and (iv) Cultural Heritage. In addition, D1.2 provides an updated planning for future iterations and outlines where key ethical, trust, and privacy concerns emerge in relation to UCs, stakeholder needs, and technological components. As the central coordination point for user testing and evaluation, WP1 plays a pivotal role in guiding the development and deployment of PRESENCE's two demonstrators by delivering validated feedback loops, experimental protocols, and context-aware design input.

Table of contents

List of Tables

List of Figures

1. Introduction

1.1. Purpose of the document

The purpose of Deliverable 1.2 (D1.2) is to provide an intermediate report within Work Package 1 (WP1), documenting progress in the Human-Centred Design process. It serves as a bridge between Deliverable D1.1 – which set out the foundations, initial requirements, and planning – and Deliverable D1.3 – which will consolidate the final outcomes.

1.2. Scope of the document

This document aims at fulfilling Milestone 4, which is the delivery of D1.2. In this context, the document provides a structured overview of the project's mid-term achievements, including:

- Validation of requirements and use case definitions.
- Results from user testing on usability and user experience (UX).
- The first iteration of presence evaluation testing.
- An overview of ethical, trust and privacy considerations across use cases, stakeholders, and technological components.
- Planning for the upcoming phase III.

1.3. Status of the document

This document is currently being prepared as part of Milestone 4 (MS4), see below. It builds directly on D1.1 and will serve as the basis for D1.3, ensuring continuity across all phases of WP1.

1.4. Relation with other activities in the PRESENCE project

WP1 serves as the foundation for WP2, WP3, WP4, and WP5. In WP1, we gather feedback on the prototypes developed in WP2 (Holoportation), WP3 (Haptics), and WP4 (Intelligent Virtual Humans). WP1 establishes the experimental protocols and requirements necessary to guide the integration and further development of the technological components of the two demonstrators in WP5.

2. WP1: Human Centred Development

2.1.1. Objectives of WP1

The objectives of WP1 are:

1. to develop a sound Mixed Method Research (MMR) framework that enables methodological innovation within the field of Human-Centred Design (HCD),
2. to define and confirm the Use Cases (UCs) and user requirements,
3. to conduct standardised usability and User Experience (UX) tests for individual technical components and the integrated systems as a whole,
4. to evaluate the UX of social and co-presence, both in individual technical components and integrated UCs,
5. to improve the effectiveness and efficiency, end-user satisfaction and accessibility, and
6. to identify ethical, trust and privacy-related issues and opportunities to guide the development of Extended Reality (XR) technologies.

2.1.2. Overview of WP1

WP1 starts M01 and finishes M36 with deliveries at Milestones MS2 (month 6), MS4 (month 18) and MS7 (month 36).

MS2: Entails delivery of Deliverable 1.1: Human-Centred Development Phase I - Foundations, Requirements and Initial Planning.

MS4: Entails delivery of Deliverable 1.2: Human-Centred Development Phase II - Intermediate User Testing, Presence Evaluation, Ethics, Trust & Privacy.

MS7: Entails delivery of Deliverable 1.3: Human-Centred Development Phase III - Final User Testing, Presence Evaluation, Ethics, Trust & Privacy.

2.1.3. Tasks & Key Performance (KPI) in WP1

WP1 has five tasks and four KPI's that need to be fulfilled by the end of the project. Tables 1 and 2 below provide an overview of them:

Task	Description
T1.1 Theoretical & methodological foundation	• Providing the theoretical backbone as well as the methodological project framework • Defining and streamlining the methods used for requirement gathering, user evaluation ensuring inclusion and diversity in recruitment of participants • Setting up an innovative MMR design to implement in the process of requirement definition (T1.2) • Combining the strengths of qualitative methods to gather requirements (internal validation) with those of quantitative methods, more specifically Multi-criteria assessment (MCA) or Multi-criteria decision making (MCDM) • IMEC will lead by developing the theoretical foundations and specifying the application of MMR design for requirement gathering and evaluation within PRESENCE • UHAM and UB will provide input on the methods for UC definition and technical requirement gathering (T1.2), Usability and UX testing (T1.3) and social and co-presence evaluation (T1.4) • Iterative validation of the framework and the applied methodology by the project partners in the first months of the project

T1.2 UC and requirements definition & validation	• Defining and validating UCs and user requirements of PRESENCE
	• Combining established HCD processes such as ISO 9241-210 with the novel framework and methodology developed in T1.1 to:
	  o Identify key users of the system
	  o Developing personas and mindsets
	• Iteratively collecting feedback on the developed prototypes (cf. WP 2, WP 3 and WP 4)

T1.3 User Centric Approach & UX testing	• Evaluation of individual technical components and the integrated systems as a whole to better understand the drawbacks and limitations of each prototype and mock-up • Performing usability studies with developers and end-users to evaluate if the provided components can be used efficiently, effectively and in a satisfying way • Using qualitative and quantitative measures as developed in T1.1

T1.4: Presence evaluation	• Evaluating presence (Place Illusion, Plausibility, Body ownership and co-presence) using the following methods:
	  o Questionnaires to give a crude and fast indication of the responses of participants
	  o Neuroscience methods to understand at a deeper level the brain mechanisms involved in responses
	  o The psychophysical methods including reinforcement learning, in order to evaluate particular configurations of factors – in particular, for analysis of the new technological advances and their combinations
	  • Sentiment analysis to get deeper insight especially for the analysis of the UCs (WP5) where the virtual environments are considered as whole.
	• Carrying out one experimental study with a minimum of 50 participants in each year of the project (for a total goal of 150 participants) that will feed back into the development of the technology and the design (T1.2)

T1.5: System Ethics, Trust & Privacy	• Identifying gender, ethical, trust and privacy related issues to guide the creation of PRESENCE technologies • Outcome is a systematic overview of possible uses for XR technology in highly contextualised scenarios to anticipate ethical issues in the development • IMEC will create an overview of different ethical themes organised by technology, UC and stakeholders so that developers can leaf through these themes to check if there are relevant themes

Table 1: Tasks within WP1

KPI nº	Description
KPI 1.1	Provide one novel mixed-methods research strategy with inclusive and diversity-oriented recruitment plans, providing human-centred requirements and UC definition of the three pillars (WP1, T1.1, T1.2, D1.1).
KPI 1.2	Analyse the three pillars in usability and UX tests with ≥ 100 participants, spanning two user groups (developers, end-users) reaching a SUS score ≥ 80 (i.e., excellent usability) and TAM score ≥ 5 (i.e., indicating high perceived usefulness and ease of use) (WP1, T1.3, D1.3).
KPI 1.3	Create a novel methodology for evaluating social and co-presence at four levels, such as place illusion, plausibility, body ownership and co-presence, analysing the impact of the new technologies and UCs, relying on experimental studies encompassing, at least, 150 participants (WP1, T1.4, D1.3).
KPI 1.4	Delivery of the ethics, trust and privacy strategy (by M18 in D1.2), describing the use of ethics, privacy and General Data Protection Regulation (GDPR) forms for a safe process involving end-users in the two demonstrators (WP1, WP7 - T1.5, T7.3, D1.2).

Table 2: KPI's within WP1

3. Progress per task

This section provides a detailed account of the activities that have been carried out within each task of the WP up to Month 18 of the project. For every task, we describe the actions taken, and highlight the key outcomes achieved so far. This comprehensive overview aims to give a clear picture of the progress made to date and how each task contributes to the overall goals of the PRESENCE project.

3.1. Planning Test Activities

In phase 2 of the project, various test activities were carried out for tasks T1.2, T1.3, T1.4 and T1.5. At the start of this phase, we drew up an initial step-by-step plan to plan these activities as effectively as possible. This step-by-step plan can be consulted via this miro board: https://miro.com/app/board/uXjVKs5vm8M=/?share_link_id=178476633562.

To keep track of the experiments conducted throughout the project, a living document[1] was created where all project partners are asked to log the experiments conducted, the goal of the experiment, amount and profile of the participants and responsible partners and tasks. Based on this document, and to provide a clear picture of the current status of participant involvement in the various tasks, the table below compares the planned and actual number of participants achieved in month 18 of the project. Where applicable, these figures are based on the targets set out in the task descriptions or associated KPIs. In cases where no specific targets have been set, participant involvement is still reported to reflect the degree of involvement. Table 3 thus shows a significant contribution has been made to all activities.

Task	Planned number of participants (until month 18 of the project)	Reached number of participants M1-18
T1.2 UC and requirements definition & validation	Not specified	45 end-users 3 Internal user tests 18 consortium partners
T1.3 User Centric Approach & UX testing	50	45 end-users
T1.4 Presence evaluation	75	292 end-users
T1.5 System Ethics, Trust & Privacy	Not specified	25 end-users 17 consortium partners

Table 3: Overview of Planned vs. Reached Participant Numbers per Task (until Month 18)

The following sections outline the activities that have been undertaken for each task so far and report in detail the results obtained.

[1] Notice to the attention of the EU officers and external reviewers: most of the below URL links direct to the project Repository and thus with access limited to the project consortium members. The documentation is available under demand, contact info@presence-xr.eu

3.2. UC and Requirements Definition & Validation

In line with the methodology outlined in Deliverable D1.1, the goal of user requirement gathering and prioritisation validation task is providing human-centred requirements and UC definition of the three pillars.

As detailed in D1.1, an Exploratory Sequential Design was chosen as part of a broader Mixed Methods Research (MMR) approach. This combines an initial qualitative phase, focused on exploration, idea generation, and the identification of user needs, with a subsequent quantitative phase that uses techniques such as Multi-Criteria Decision Making (MCDM) to structure and prioritize requirements [Ref. 1]. The methodological approach was designed to be iterative, allowing the project team to refine requirements continuously throughout the development process, integrating input from both consortium partners and end-users. The following sections outline how this process was initiated and implemented. The first section in this chapter addresses the prioritisation of the initial set of requirements (which were reported in D1.1) by consortium members. Second, the user requirements gathered from evaluation activities with end-users are discussed. Third, the end-user feedback on the first playable app (UC validation round 1) is addressed. Fourth, the end-user feedback on PRESENCE app V0 (UC validation round 2) concludes the insights gathered between M7 and M18 for T1.2. Section 3.2.5 closes with lessons learned, which highlight the practical lessons that will inform the approach for the next project phase.

3.2.1. Requirements prioritisation with consortium partners

Prioritisation methodology

As reported in D1.1, 4 series of online co-creation workshops were held at the end of April 2024 with consortium partners to gather the first set of requirements (see D1.1, section 6). Following this initial qualitative phase, a quantitative prioritization method was adopted to ensure systematic evaluation of the gathered requirements. The selected method, the Weighted Scoring Model (WSM), is a multi-criteria decision-making technique commonly used to rank alternatives based on their relative importance across several dimensions [Ref. 2]. During a consortium meeting held after the initial co-creation sessions, it was decided that the criteria for prioritization would include: impact (the degree to which a requirement affects users or the product), urgency (how critical it is to implement), cost (the estimated economic expense), and technical feasibility (how achievable it is from a technical perspective). All consortium partners were invited to assign weights to these criteria through an online survey, which resulted in the following distribution: 24% for impact, 21% for urgency, 19% for cost, and 36% for technical feasibility.

Once all requirements were consolidated into a single list, they were further categorized into eight separate lists: one for each of the three technical pillars, four for the UCs (excluding technical pillar references), and one general requirements list. This categorization aimed to prevent partners from needing to assess requirements outside their area of expertise. Partners were then asked to score each relevant requirement from 0 to 10 against the predefined criteria. The final prioritization was calculated using the average weighted scores assigned by all contributing partners. In a final step, partners were also asked to identify which organization(s) would be responsible for implementing each requirement. A comment box was included to allow for any additional input, clarification, or expression of uncertainties regarding specific items.

All lists were structured in the same format that included the following fields: ID, Code, User/Technical, Functional/Non-Functional/NA, Version, Link TR/UR, Technical pillar, UC, Category, Requirement, Specification on requirement (if needed), Responsible partner(s), Execution date, Technical feasibility, Overall prioritisation score, Type of user, Origin, Average score on impact, Average score on urgency, Average score on cost, Average score on technical feasibility, Scope, Milestone, Linked WP/Task, Means of validation, Discussion.

Figure 1: User requirement workshop with partners at the GA (Porto, January 22nd 2025)

Prioritisation results across the user requirements lists

In this section, the priorities the consortium has identified are presented. Because of the extensive nature of the requirement list, only the highest priority categories are reported. The initial lists of requirements can be consulted in the working document.[2]

Across all reviewed requirement lists – spanning the three technical pillars ((i) holoportation, (ii) digital touch, (iii) intelligent virtual humans), general system needs, and the four UCs – a number of overarching priorities and thematic patterns, following a thematic analysis [Ref. 3] of the results, emerge that collectively reflect the project's commitment to user-centered, technically robust, and context-sensitive virtual experiences.

Collaboration is a recurring high-priority theme, particularly evident in the general requirements and the professional collaboration UC (UC1.1). This emphasis suggests a strong vision for multi-user environments in which co-presence, coordinated interaction, and fluid teamwork are essential. Whether through shared manipulation of objects, real-time communication, or synchronized actions, enabling meaningful interaction between users is central to many of the system's intended applications.

Realism is another consistent concern, especially in UCs where fidelity to the physical world is crucial, such as manufacturing training (UC1.2) and cultural heritage (UC2.2). In these scenarios,

[2] Notice to the attention of the EU officers and external reviewers: most of the below URL links direct to the project Repository and thus with access limited to the project consortium members. The documentation is available under demand, contact info@presence-xr.eu

realism not only supports immersion but is directly tied to user outcomes, such as transfer of learning or authentic engagement with cultural narratives. This focus is also mirrored in the technical pillars, particularly intelligent virtual humans (IVH), where the representation and behavior of avatars must be believable to foster trust and presence.

Ease of Use and **User Support**, **Guidance**, and **Assistance** stand out across multiple contexts. Whether through clear user guidance in training applications (UC1.2), or intuitive configuration and setup tools for holoportation and IVH, there is a clear push to lower technical barriers and make systems more accessible to non-expert users. The presence of categories like **Easy Use**, **General Usability**, and **User Support**, **Guidance**, and **Assistance** in the top prioritised items underlines this imperative for usability and practical deployment.

Multimodality and **Synchronization** are especially prominent in the digital touch (haptics) pillar, but also relevant across domains. Ensuring that visual, auditory, and haptic cues are well-aligned is not only a technical requirement, but one that directly influences immersion, user confidence, and emotional comfort. Similarly, real-time interaction, identified as a top priority in UC2.2 (cultural heritage) and UC1.2 (training), underscores the broader need for responsiveness and temporal accuracy across system modalities.

Comfort and Relaxation, as seen in the health UC (UC2.1) and in the digital touch and IVH pillars, further highlights the importance of designing for the full human experience. Comfort is treated not only as an ergonomic concern, but also in terms of emotional safety, cognitive load, and environmental relaxation, especially critical for vulnerable user groups like patients.

Deployment practicality also emerges as a key consideration, particularly in the holoportation pillar, where environmental constraints, setup complexity, and network stability must be addressed to ensure reliable operation. Similarly, the health UC prioritises hygiene, scalability, and ease of cleaning, reminding us that Virtual Reality (VR) deployment is as much about physical and organizational integration as it is about digital features.

Accessibility and Inclusivity, and **Compliance** appear across cultural heritage and health contexts, emphasizing the need to accommodate a diverse range of users while ensuring that content and technologies adhere to appropriate cultural, legal, and institutional standards. This reflects a growing awareness of the responsibilities inherent in designing immersive experiences that interact with sensitive topics or diverse populations.

In summary, the most prominent cross-cutting requirements across technical pillars and UCs point to a unified vision: one that combines technical robustness (performance, real-time responsiveness, deployment readiness) with human-centered design (comfort, inclusivity, emotional support, usability), and a collaborative ethos (shared tasks, social interaction, and immersive co-presence). These interconnected themes form the foundation for the PRESENCE system's development strategy, ensuring that technology serves not only functional goals but also the nuanced needs of users in real contexts.

Below we outline the insights for each list.

Prioritisation results for Holoportation

The analysis of the holoportation-related requirements reveals that the **Deployment** category contains several of the most highly prioritised items. These requirements emphasize the importance of appropriate environmental conditions for system setup, such as avoiding direct sunlight, mirrors, or infrared interference in the installation space. The consistent presence of deployment-related items at the top of the prioritisation list suggests that practical considerations around physical placement and readiness of the system are seen as critical for successful implementation.

Performance is another prominent category, with several requirements focusing on the technical infrastructure needed to ensure smooth operation. These include the need for stable and high-speed internet connections, as well as local Ethernet support, highlighting the importance placed on low-latency, high-bandwidth environments necessary for real-time holoportation functionality.

Requirements under **System Control** also rank highly, particularly those related to configuration support and usability. This includes providing built-in tools for system setup and clear user guidelines, reflecting a strong emphasis on ensuring the system is manageable, user-friendly, and adaptable to different operational contexts.

Finally, the **Collaboration** category is also represented among the most prioritised requirements, pointing to the value placed on enabling shared remote interactions. This indicates that beyond technical performance and setup, the ability to support multi-user scenarios is seen as an essential feature of a well-functioning holoportation system.

In summary, the most prominent requirements focus on ensuring that holoportation is technically stable, easy to deploy and configure, and capable of supporting collaborative use, underscoring the need for a seamless integration of system functionality, usability, and real-world applicability.

Prioritisation results for Digital Touch (Haptics)

The review of requirements related to the Digital Touch (Haptics) technical pillar shows a strong emphasis on enhancing how users physically interact with the system. The largest number of highly prioritised requirements fall under the category **Interaction with System**, suggesting a clear focus on refining the tactile engagement between users and haptic devices. These requirements cover aspects such as gesture responsiveness, feedback consistency, and integration with virtual elements.

The **Synchronization** category holds the highest average score, pointing to the critical need for haptic feedback to be closely aligned in timing with visual and auditory cues, ensuring a cohesive multisensory experience. Similarly, Presence and Plausibility emerges as a key concern, underlining the role of realistic and believable tactile sensations in reinforcing user immersion.

The presence of categories such as **Comfort and Relaxation**, and **Distraction** also indicate that the project partners are attentive not only to technical accuracy but also to the overall quality and comfort of the user experience. These insights suggest that while technical precision remains essential, user perception and comfort are equally valued in the development of haptic interactions within the PRESENCE app.

Prioritisation results for Intelligent Virtual Humans

The analysis of the requirements related to the Intelligent Virtual Humans (IVH) technical pillar highlights a diverse range of priorities across several categories. Among them, **Representation** emerges with the highest average prioritisation score, indicating a strong emphasis on how virtual humans are visually and behaviorally rendered. This suggests that partners place significant importance on ensuring that virtual characters appear believable and realistic, which is critical for presence, trust, and engagement during user interaction.

Performance is another highly prioritised category, comprising several requirements that focus on the technical capabilities of virtual humans, such as their responsiveness, processing efficiency, and ability to operate in real time. This reflects the need for smooth and consistent behavior from virtual agents.

Other relevant categories include **Comfort and Relaxation**, which underscores the importance of creating emotionally supportive and non-disruptive virtual experiences.

Meanwhile, the **Collaboration** category highlights the role of virtual humans in enabling or supporting shared tasks and interactions between users, pointing to their function not only as individual entities but also as social agents in multi-user environments.

Finally, the presence of **Easy Setup** as a prioritised category reflects practical concerns about how virtual humans are integrated into the system and accessed by end users. This may involve simplifications in configuration, scenario loading, or character initialization, ensuring that IVH elements can be efficiently deployed in diverse contexts.

Overall, the requirements indicate that Intelligent Virtual Humans are expected to be not only technically reliable and realistic in appearance but also easy to deploy, emotionally considerate, and socially functional within multi-user settings.

Prioritisation results for General system requirements

The analysis of the general requirements, which are not tied to specific UCs or technological pillars, shows a strong emphasis on user experience and system-wide functionality. The **Collaboration** category holds the highest average prioritisation, underscoring the importance of supporting shared experiences and coordinated tasks across users. Requirements in this category address features that facilitate smooth and meaningful interaction among multiple participants in a shared virtual environment.

Close behind is the **Multimodal** category, which reflects the value placed on integrating different sensory modalities, such as visual, auditory, and haptic channels, into a cohesive user experience. High prioritisation here suggests that ensuring the system delivers synchronized and well-aligned multisensory feedback is considered a key factor in user engagement and immersion.

Social Interaction also ranks prominently, indicating that enabling natural, believable interpersonal interaction in the virtual environment (VE) is an important cross-cutting requirement. This includes the ability to convey non-verbal cues, respond to user presence, and simulate human-like behavior in shared spaces.

Categories such as **Comfort and Relaxation** and **General Usability** also received consistently high scores. These findings reflect a broad focus on making the system accessible, comfortable, and intuitive for users. The General Usability category, in particular, includes a large number of requirements and shows a strong overall prioritisation, confirming the importance of ease of use, responsiveness, and user-friendly design.

Together, these results suggest that, beyond technical excellence, substantial value is placed on delivering a socially engaging, user-centered, and multimodal experience that supports collaboration, reduces friction, and enhances overall comfort for diverse users.

Prioritisation results for UC 1.1 Professional Collaboration

The requirements identified for UC1.1, which focuses on the professional collaboration UC and are not tied to specific technical pillars, emphasize several key experiential and interaction-related priorities. At the top of the prioritisation ranking is the **Collaboration** category, reflecting the central role of shared task performance, mutual engagement, and fluid cooperation in this UC. This highlights the importance of features that enable multiple users to interact seamlessly in a virtual workspace, such as synchronised actions, shared interfaces, or co-manipulation of virtual objects.

Other highly prioritised categories include **Reality and Plausibility** and **Social Interaction**, both of which point to the need for immersive, believable environments where users can interact naturally. The focus on reality and plausibility suggests that users should feel as though the VE and their actions within it are coherent and credible, reinforcing the overall sense of presence. Meanwhile, social interaction requirements emphasize natural communication and responsiveness between users, which is essential for effective teamwork in virtual settings.

The categories **Realism** and **Effectiveness** also appear among the top-rated, indicating that visual fidelity, behavioral accuracy, and the ability to achieve concrete goals within the environment are also seen as vital. These priorities suggest that UC1.1 is not only concerned with enabling collaboration, but also with ensuring that the environment and interactions support productive, realistic, and goal-oriented work sessions.

Together, these insights show that the most important requirements for UC1.1 center on creating a VE that is socially engaging, perceptually convincing, and functionally supportive of professional collaboration.

Prioritisation results for UC 1.2 Manufacturing Training

The analysis of the requirements for UC 1.2, focused on manufacturing training and not tied to any specific technical pillar, reveals a clear emphasis on enhancing the quality and effectiveness of the training experience. The highest-ranked category is **Realism**, which highlights the importance of creating a virtual training environment that closely mirrors real-world scenarios. This includes visual fidelity, realistic object behavior, and believable spatial interactions, all crucial for enabling users to apply their virtual training to real-life contexts.

Closely following is the category of **User Support, Guidance, and Assistance**, underscoring the need for systems that provide clear instructional cues, contextual help, and responsive feedback during training activities. This focus indicates that users are expected to navigate training environments independently, making built-in support mechanisms essential for task comprehension and learning efficiency.

The category of **Training and Simulation** itself is also prominently represented, reflecting the overall goal of the UC. Requirements here address the structuring of training flows, interaction with learning modules, and the ability to simulate various training scenarios with consistency and repeatability.

Real-time Interaction is also a highly prioritised category, pointing to the importance of immediate system responses to user actions. This ensures a fluid and immersive experience where delays or lag do not disrupt the sense of engagement or learning progression.

Finally, the **Flexibility** category appears among the top priorities, indicating the importance of adaptable system behavior. This includes the capacity to personalize or adjust training experiences based on user profiles, skill levels, or learning goals.

Overall, the most valued requirements in UC 1.2 center on realism, instructional support, simulation quality, responsive interaction, and adaptability, all critical elements for delivering an effective and immersive remote training experience.

Prioritisation results for UC 2.1 Health

The requirement analysis for UC 2.1, focusing on a health-related scenario and not tied to any specific technical pillar, highlights several user-centric priorities. The most highly prioritised category is **Distraction**, reflecting the critical role of minimizing unnecessary sensory input or interaction complexity in healthcare settings. This suggests a strong need to create calming, focused virtual environments that do not overwhelm or confuse patients, particularly important when dealing with vulnerable users.

Hygiene also emerges as a key concern, alongside Scalability, with both categories showing similar levels of prioritisation. Requirements in these areas address the practical realities of deploying VR solutions in clinical settings, ensuring that systems are physically cleanable, shareable across users, and scalable to different patient groups or institutional setups. This indicates that usability in real-world healthcare contexts is seen as just as important as the immersive experience itself.

The **Easy Use** category is also highly valued, reinforcing the emphasis on simplicity and accessibility. This reflects the need for systems that can be easily operated by a diverse range of users, including patients with little or no technical background.

Lastly, **Comfort and Relaxation** is the most populated category in terms of number of requirements, showing consistent prioritisation. This indicates that the overall emotional and physical comfort of the user, whether related to headset ergonomics, environmental design, or the pacing of experiences, is fundamental to delivering a successful health-focused VR application.

Overall, the most critical requirements for UC 2.1 revolve around making the virtual experience calming, hygienic, scalable, easy to use, and supportive of comfort, all of which are central to ensuring effectiveness and safety in healthcare-oriented VR use.

Prioritisation results for UC 2.2 Cultural Heritage

The requirements gathered for UC2.2, focused on the cultural heritage UC and not associated with any specific technical pillar, reveal a strong prioritisation of real-time interactivity and experiential authenticity. The top-ranking category is **Real-time Interaction**, indicating a clear emphasis on enabling immediate and seamless user actions within the virtual cultural environment. This suggests that responsiveness, whether in navigating the space, triggering content, or engaging with multimedia elements, is viewed as fundamental to creating a compelling cultural experience.

Presence and Plausibility also scores highly, underscoring the importance of immersing users in believable, contextually rich environments. For a cultural heritage setting, this likely includes visual realism, historical accuracy, and environmental continuity that together foster a strong sense of being “present” in another time or place.

Closely following is **Accessibility and Inclusivity**, which, though represented by a single requirement, ranks among the highest. This reflects the need for cultural content to be reachable and engaging for diverse audiences, including users with different physical abilities or levels of technical experience.

The **Compliance** category also features prominently, suggesting that adherence to ethical, legal, or institutional standards is a vital concern in the cultural heritage context. This may involve respecting data protection regulations, attribution of content, or ensuring that cultural material is treated sensitively and appropriately.

Finally, the **Support** category highlights the importance of offering users contextual assistance, whether through instructions, navigation aids, or background information, to help them meaningfully engage with the content.

Together, the most highly prioritised requirements in UC2.2 reflect a balanced concern for real-time responsiveness, immersive authenticity, inclusivity, ethical integrity, and user guidance, demonstrating a comprehensive approach to designing impactful virtual cultural experiences.

3.2.2. User requirements gathered from workshops with end users

As outlined in D1.1, the initial lists of user and technical requirements as presented in section 3.2.1, will be continuously refined based on new insights gathered from user testing with the PRESENCE applications. This iterative approach ensures that the requirements remain closely aligned with real user experiences and system interactions. To this end, IMEC conducted user tests with the First Playable app (see section 3.2.3) and the Version 0 (V.0) PRESENCE app (see section 3.2.4) in March, April, and May 2025. Figure 2 depicts users testing the First Playable app (A) and the V.0 PRESENCE app (B).

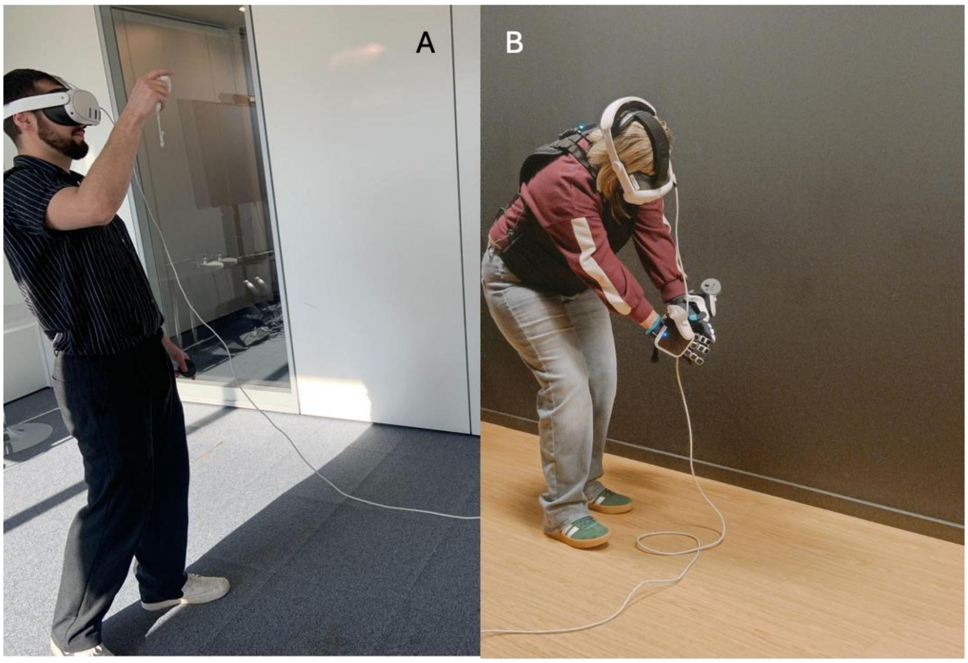


Figure 2: User Evaluations First Playable app (A) and V.0 PRESENCE app (B)

For each UC (Professional Collaboration, Manufacturing Training, Health and Cultural Heritage) evaluation activities were set up with the aim to validate the UCs and requirements with end users, in combination with the user centric approach and UX testing (T1.3), and the System Ethics, Trust and Privacy task (T1.5). Insights from the user tests with the First Playable apps and the V.0 PRESENCE apps allowed the identification of new requirements, which are presented in this section.

User requirements gathered from testing the First Playable app

The insights derived from the user tests with the First Playable app were translated into user requirements. Table 4 shows the user requirements that emerged from each UC evaluation (based on the interviews with participants). These requirements will be further analysed in the next steps together with the consortium to assess their feasibility. They will also be compared with the existing lists of requirements to determine which ones correspond to the original requirements and which ones are new. This will allow us to classify them correctly and include them in the appropriate list.

User Requirements: First Playable app			
UC1.1 Professional Collaboration	**UC1.2 Manufacturing Training**	**UC2.1 Health**	**UC2.2 Cultural Heritage**
The user shall be able to use the system without requiring a large physical space.	The user shall be able to manipulate virtual objects with minimal confusion or friction.	The user shall be able to receive clear and understandable instructions throughout the experience.	The user shall be able to use the system comfortably even with reduced mobility.

The user shall be able to use the system with alternative control methods if physically impaired.	The user shall be able to perform joint tasks with others, even when inputs occur simultaneously.	The user shall be able to feel comfortable and relaxed within the virtual environment.	The user shall be supported by an in-experience guide when they get stuck.
The user shall be able to access VR systems through public or workplace facilities.	The user shall receive feedback and interact with virtual objects in a way that feels physically realistic.	The user shall be able to interact with virtual elements without excessive head movement or unnatural arm extensions.	The user shall be able to follow a clear narrative throughout the experience.
The user shall be provided with basic training for VR usage.	The user shall be able to engage in multi-user collaboration with minimal delay and highly accurate synchronization.	The user shall be able to experience a visually appropriate and thematically mature environment suitable for adult users.	The user shall be able to read subtitles or projected text instead of relying solely on audio.
The user shall be able to choose from different interaction methods (voice, text, video).	The user shall be informed about what data is being tracked (e.g., eye gaze, motion), how it is used, and by whom.	The user shall be able to switch between the virtual and real environment for reassurance or comfort.	The user shall be presented with unskippable historical data to ensure comprehension of context.
The user shall be represented fairly and accurately in avatar design.	The user shall have control over whether AI can access or process their personal data, including speech and behavioral inputs.	The user shall be able to understand and control what personal data is collected, stored, and used during the experience.	The user shall receive a disclaimer stating that the VR experience is a dramatized or fictionalized version of real events.
The user shall have all their data stored in an encrypted location.	The user shall be informed if their training performance is being recorded or monitored, and for what purpose, to reduce unnecessary stress or performance anxiety.	The user shall be able to give or withhold consent for sharing sensitive data, such as emotional state.	The user shall be protected from trauma triggers by being able to adjust or reduce the intensity of the simulation.
The user shall be able to delete their data on demand with full transparency.	The user shall be protected by clear behavioral guidelines and system rules that address inappropriate conduct, including how such actions are detected and managed.	The user shall be able to have their emotional cues detected and responded to by the system.	The user shall be able to engage in gamified elements such as stealth mechanics (e.g., staying quiet to avoid detection).

The user shall be protected against unauthorized data access by other users.	The user shall be warned or protected from overly graphic or harmful content when performing unsafe actions (e.g., placing an arm in a virtual press).	The user shall be able to adjust the level of sensory stimulation to match their comfort level.	The user shall be given sufficient explanation about characters or roles within the scenario.
The user shall be able to use an offline AI assistant that does not store data online.	The user shall be able to perform realistic and natural movements where needed to correctly and safely learn procedures.	The user shall be able to access the system in their preferred language to ensure accessibility.	The user shall experience tightness via a haptic vest to simulate the narrowness of historically accurate spaces.
The user shall experience realistic gravity effects on objects.	The user shall be able to perceive visual effects that represent environmental conditions, including heat distortion.	The user shall have the option to select personalized music for their experience.	The user shall be guided throughout the experience with contextual information about the history and tasks to maintain focus and understanding.
The user shall not be able to phase through walls or objects.	The user shall be able to hear audio cues that convey environmental stress, including the creaking of metal.	The user shall be provided with hardware options that accommodate different physical needs, including varying equipment sizes and accessibility for patients with disabilities.	The user shall be able to adjust the experience to fit their physical needs or limitations, including movement requirements and interaction difficulty.
The user shall be able to accurately control teleportation within the virtual space.	The user shall be able to access the experience without requiring high-cost equipment such as high-end computers or HMDs.	The user shall be able to set up and use the system through a simple and time-efficient process suitable for healthcare workers.	The user shall have the option to avoid or modify physically demanding tasks (e.g., crawling or digging) to accommodate mobility restrictions or phobias such as claustrophobia.
The user shall be able to raise/lower a chair.	The user shall receive clear instructions about what to do in the environment, why tasks are performed, and how to interact with objects, regardless of prior VR experience.	The user shall be guided clearly through the experience with tutorials or step-by-step instructions, accessible at any time if the user forgets how to interact.	The user shall have access to comfort settings (e.g., volume, motion intensity, visual effects) to help reduce cybersickness and disorientation.

The user shall be able to interact with documents within the virtual environment.	The user shall be able to navigate the VE using control-based movement, enabling access for those with limited physical mobility.	The user shall be able to use the system comfortably even with visual impairments, including compatibility with glasses and visual design that avoids overwhelming stimuli.	The user shall be able to select different difficulty levels, where lower levels offer more support and guidance, and higher levels allow for more autonomy and exploration.
The user shall be able to customize the VE's appearance.	The user shall have access to adjustable session lengths or comfort settings to help reduce cybersickness and support varied user tolerances.	The user shall be able to customize sensory elements of the environment to accommodate cognitive needs (e.g., for users with autism or dementia), including simplifying surroundings or reducing stimuli.	The user shall be clearly informed about what types of data are collected and how this data will be used.
The user shall be able to access the experience without requiring high-end or expensive hardware.	The user shall be able to experience the application in their preferred or native language to prevent misunderstandings or missed information.	The user shall be able to choose from different distraction or difficulty levels, to adjust the level of engagement according to their comfort or anxiety levels.	The user shall be protected by behavioral regulations that define how misconduct or abuse within the experience is tracked, handled, and stored.
The user shall be able to feel and interact with virtual elements through haptic gloves that provide accurate feedback.	The user shall be guided through tasks using game-like elements such as mission boxes or checklists that clearly show what needs to be done and in what order.	The user shall experience visual representations in the VE that correspond to real-world physical events (e.g., blood being drawn), in order to maintain immersion.	The user shall experience historically accurate content that avoids romanticizing or distorting sensitive subjects, in order to preserve educational value and authenticity.
The user shall be able to navigate and use the experience with minimal prior knowledge of VR, supported by onboarding guidance.	The user shall be able to choose what personal information to share before starting the experience.	The user shall be informed about what data is collected and how it will be used, with consent mechanisms suitable for short medical procedures.	

The user shall see diverse and inclusive representation of people from all ethnic backgrounds within the virtual environment.			
The user shall be protected from unwanted exposure of their physical environment during holoportation (e.g., when connecting from a private space like home).			
The user shall be informed about who can access their holoportation body scan data and how long it is stored.			
The user shall have control over whether AI systems can access or process their holoportation body scan data.			

Table 4: User Requirements derived from First Playable app tests

For the **Professional collaboration UC (UC 1.1)**, the requirements show that the system needs to be designed to be widely accessible and inclusive, accommodating users regardless of physical ability, available space, or prior experience with VR. There is a strong focus on flexibility in interaction methods, such as voice, text, or video, and on providing onboarding support. Privacy and data security should be prioritized through encryption, user control over data deletion, and offline Artificial Intelligence (AI) functionality. Users expect to experience realistic physical properties like gravity and be prevented from moving through virtual objects. Customization, affordability, and inclusive representation are also central to this UC, highlighting a commitment to equitable access.

In assessing the **Manufacturing Training UC (UC 1.2)**, the requirements highlight the importance of delivering a seamless, realistic, and collaborative virtual experience. Users expect to interact with virtual objects effortlessly, collaborate with others, even during simultaneous actions, and receive natural, real-time feedback. Strong emphasis is placed on precise synchronization in multi-user environments. Transparency is a key concern, with users needing clear information about what data is being collected, how it is used, and who has access. Consent mechanisms are essential. Additionally, the system must include safeguards to address safety, appropriate conduct, and sensitive content. To support a wide range of users, the experience also incorporates language support, accessible movement options, and gamified guidance to keep navigation intuitive and engaging.

For the **Health UC (UC 2.1)**, the requirements show a strong emphasis on emotional well-being and accessibility, particularly for healthcare or emotionally sensitive applications. Users must feel comfortable and guided through clear instructions, minimal physical strain, and environments that are thematically appropriate for adults. Data privacy should be tightly controlled, with consent mechanisms in place for emotional or sensitive data. Sensory customization, such as adjusting visual, auditory, or cognitive stimulation, is a considerable key to making the experience supportive of individuals with varied needs. Easy setup, language support, and personalization (like selecting music) could reflect a design that values user comfort and clarity throughout.

The requirements that were identified in the feedback on the **Cultural Heritage UC (UC 2.2)** indicate that users expect a historically immersive experience that is both educational and emotionally sensitive. Accessibility remains a key concern, with accommodations for users with limited mobility, as well as features like subtitles and narrative guidance. To mitigate the impact of intense or potentially triggering content, users expect to be provided with disclaimers and options to adjust the experience. According to the users, realism can be enhanced through tactile feedback, such as simulating tight spaces, and interactive, game-like elements. The experience should deliberately avoid glamorizing or distorting sensitive historical events, instead it should emphasize structured learning, contextual storytelling, flexible difficulty levels, and clear behavioral standards. Respect for data privacy and historical accuracy underpins the entire design.

User requirements gathered from testing the V.0 PRESENCE app

The user tests conducted with the V.0 PRESENCE app provided valuable insights that were translated into user requirements (Table 5). The following section outlines the specific requirements identified during the evaluation of each UC (based on the interviews with participants). In the next steps, these will be reviewed in collaboration with the consortium to evaluate their feasibility. They will then be cross-checked against the existing requirement lists to identify overlaps with previously defined needs and to highlight any newly emerging ones. This process will ensure that all requirements are accurately categorized and added to the appropriate list.

User Requirements: V.0 PRESENCE app			
UC1.1 Professional Collaboration	**UC1.2 Manufacturing Training**	**UC2.1 Health**	**UC2.2 Cultural Heritage**
The user shall be able to teleport accurately and easily within the virtual environment.	The user shall be able to use natural hand gestures to interact with virtual objects.	The user shall be able to interact with a variety of environmental objects (e.g., lamps, PCs, iPods) to enhance interactivity and engagement.	The user shall be able to perform a tapping gesture that is consistently recognized and not misinterpreted as a teleportation command.
The user shall be able to grab and move virtual objects, such as chairs and buttons, using natural hand movements.	The user shall be able to place objects accurately within the virtual space without unnatural snapping or floating.	The user shall perceive other users' presence through visible body movement and nonverbal cues such as waving or gestures.	The user shall be able to teleport only when performing the correct input gesture, without unintentional activation.

The user shall receive haptic feedback through gloves that reflects localized sensations on different fingers.	The user shall be able to collaborate with other users by performing synchronized or simultaneous actions, such as pressing buttons together.	The user shall be able to receive clear and interference-free audio feedback, with music and ambient sounds not obstructing comprehension.	The user shall be able to press virtual buttons with gestures that are accurately recognized by the system.
The user shall be able to grasp virtual objects naturally without premature or incorrect haptic blocking.	The user shall be able to interact with a holoported supervisor or team member through coordinated tasks and visible body language.	The user shall be able to distinguish roles and relationships (e.g., nurse, patient, visitor) through avatar appearance and behavior.	The user shall be able to pick up objects using grab gestures that are reliably detected, even when items are on the ground.
The user shall be able to interact with minimal motion or hand-tracking lag or inconsistencies.	The user shall be able to recognize and respond to nonverbal communication, such as waving or body gestures, during interactions with holoported persons.	The user shall feel physically comfortable and emotionally safe when receiving haptic feedback through gloves or vests, especially during interpersonal interactions.	The user shall be able to aim and select interactive elements using a targeting mechanism that aligns precisely with hand positioning.
The user shall receive realistic environmental haptic feedback, avoiding unnecessary or inaccurate vibrations.	The user shall receive realistic haptic feedback when grabbing, pressing, or interacting with virtual elements, including sensations that reflect weight, resistance, or texture.	The user shall be able to follow conversations between avatars and AI agents, even when not directly engaged in the interaction.	The user shall be able to complete tasks, such as using a swing or connecting cables, without gesture recognition failures.
The user shall be represented by a naturalistic avatar with accurate body and hand alignment.	The user shall be able to understand their spatial position through realistic object physics and consistent environmental behavior.	The user shall be able to interact with humanoid avatars without confusion regarding their roles or identities.	The user shall have access to a tutorial to practice teleportation before beginning the main experience.
The user shall perceive the presence of others through accurate representations of their body and hand movements.	The user shall be able to interact with the system without being physically tethered, allowing for greater movement and comfort.	The user shall be able to interact with avatars capable of basic nonverbal behaviors such as eye contact, facial expressions, and nodding, to support natural communication.	The user shall have access to a tutorial to practice using haptic gloves before beginning the main experience.

The user shall experience holoportation that conveys a complete and realistic human representation.			
The user shall be able to see their own virtual body and spatial orientation within the VE.			
The user shall be able to walk physically in the VE, provided hardware allows it.			
The user shall receive instructional prompts or guidance within VR to assist with interactive tasks and elements.			
The user shall be able to manipulate 3D objects collaboratively, including actions like rotating and lifting.			

Table 5: User Requirements derived from V.0 PRESENCE app tests

The requirements reflecting the feedback on the **Professional Collaboration UC (UC1.1)** show that users expect to interact within the VE using natural and precise controls. Users need to teleport accurately, grab and manipulate objects like chairs and buttons through intuitive hand gestures, and receive haptic feedback that feels realistic and localized across different fingers. They expect interactions to be smooth, without noticeable lag or misalignment. Users also want to see their virtual bodies, including spatial orientation, and perceive others realistically through detailed avatars and full body holoportation. Movement should be possible physically where hardware allows, and guidance should be embedded in the experience to support interaction with 3D elements.

For **Manufacturing Training (UC1.2)**, users expect the system to support fluid, natural hand gestures for manipulating virtual elements. The requirements show that interactions should be accurate and physically realistic, such as placing objects without awkward floating or snapping. Collaborative tasks with others, like pressing buttons together, should be synchronized and visually coherent. Users also want to communicate nonverbally through body gestures or waving and to work alongside holoported colleagues through shared visual and task-based cues. They expect the environment to feel physically grounded, with physics-based interactions and no restrictions from tethers or cables.

In a **Health** environment **(UC2.1)**, the requirements highlight that users need to engage with a rich and interactive environment where everyday objects (e.g., lamps, Personal Computers (PC)) respond realistically. Users expect to detect others' presence through natural gestures, body language, and eye contact. Audio feedback must be clear and non-intrusive, and users want to recognize roles, such as patients or professionals, through how avatars appear and behave. Emotional and physical comfort is also a key expectation, especially when using haptic equipment. Conversations with AI or avatars should be easy to follow, even from the periphery, and the system should support natural human communication through facial expressions and behavioral cues.

For the **Cultural Heritage UC (UC2.2)**, the requirements show that users expect precise gesture recognition, especially for basic actions like tapping, teleporting, grabbing, or pressing virtual buttons. They need assurance that gestures won't be misinterpreted or accidentally triggered. Accuracy is critical for ground-level interactions and fine targeting using hand alignment. Users also expect to complete complex physical tasks, such as using swings or connecting cables, without failures. To support readiness and reduce errors, users expect tutorials to practice key interactions (e.g., teleportation, haptic glove use) before engaging with the full experience.

In the following phases, the initial requirement lists will be reviewed and updated by consortium partners. The new requirements will be jointly assessed to determine their technical feasibility within the project and to check whether they are already reflected in the original lists. If not, the relevant lists will be amended accordingly. Prioritisation of the new requirements is also necessary. This process supports a responsive and evidence-based approach to requirements gathering, reinforcing the project's commitment to user-centred design.

3.2.3. UC validation round 1: First Playable app testing

A first environment, labeled 'First Playable App' was developed separately for each UC and served as a foundational version. These versions did not yet integrate the technical pillars from WP2–4. They included basic user representation via standard avatars and focused on simple object interactions, without advanced features such as holograms, digital touch, or intelligent virtual humans (see also Figure 3, left).

IMEC conducted end-user tests at the offices of IMEC-SMIT on the 24th and 28th of March, and on the 1st and 2nd of April 2025. For the Professional Collaboration UC1.1 (2 participants) and the Cultural Heritage UC2.2 (4 participants), participants tested the app and were first interviewed briefly about their initial impressions. Afterwards, they completed a survey from UHAM covering both UX and presence evaluation (see Section 3.3.3). Finally, a 3-hour workshop was held with all participants who had tested the UC apps to gather insights on the UC viability and ethical considerations. Participation was limited due to a train strike in Belgium which hindered interested participants. Therefore, for the Manufacturing Training UC1.2 (8 participants) and the Health UC2.1 (11 participants), the methodology was adjusted. In these UCs, participants only took part in 1-on-1 interviews instead of a 3-hour evening workshop.

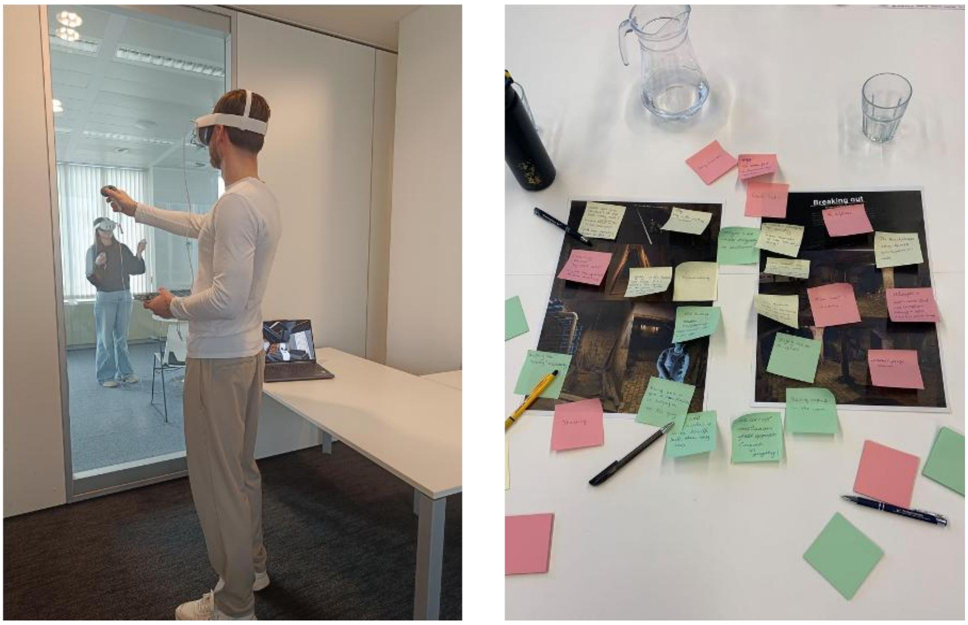


Figure 3: UC Validation Workshop First Playable app

Recruitment efforts mainly aimed towards including a diversity of students and personnel from all kinds of departments at the Vrije Universiteit Brussel and IMEC-SMIT.

Use Case Validation Methodology

<u>Testing the app</u>

These sessions followed the protocol written by IMEC, which allowed the researchers to get insights into how the users perceived the app/experience (see Adjuncts sections 8.1 and 8.2). During this session, the researchers asked open questions to gather initial feedback on the experience of the participants, assessing how they feel in the environment in general, how they experienced interaction in and with the environment, how they evaluated interaction with other participants in the environment and what their general first impressions were.

<u>Workshop and interviews</u>

After testing the first playable app, participants were asked more in-depth questions about their experience during a workshop or interview. At the beginning of the workshop, participants were divided into three groups of three to four participants. Each group then gave feedback and input on the first playable app itself in an exercise called **Rose-Thorn-Bud**, where they put post its with their feedback on a picture of the app environment, answering the following questions:

- *What aspects of the experience did you like the most?*
- *What aspects of the experience did you not like?*
- *What opportunities are there to improve the experience?*

After having written down their feedback on the post-its, a group-discussion was facilitated where participants could further expand on what they had written, giving us a deeper understanding of the feedback and what aspects of the environment they liked, disliked and/or could be improved. On the righthand side, Figure 3 represents the outcomes of the rose-thorn-bud exercise of one of the workshops.

For the interview, the questions asked to gather feedback on the UC apps remained the same: participants were asked about their first impressions of the app they tested, and if there was something they liked or disliked, and what they would like to improve about the app.

Analysis

The workshops and interviews were audio-recorded and subsequently transcribed using Scribewave. The transcripts were analyzed in MAXQDA, utilizing its AI-supported features to efficiently identify key themes and feedback due to limited time. To ensure the reliability of the findings, all outputs generated by the AI were carefully reviewed and validated by the research team, addressing any potential errors or oversights in interpretation.

Results UC1.1 Professional collaboration

Description of the VR experience

In the multi-user professional collaboration UC, two participants find themselves in a virtual meeting room designed for brainstorming sessions with others. Upon entering the space, they see a central 3D model of an office chair, the focal point of the discussion. Participants can interact with the chair by grabbing and moving it, allowing them to view it from different angles and closely examine its design details. In addition to interacting with the chair, participants see a whiteboard in the meeting room where they can write notes, sketch ideas, and capture key points from the discussion in real time. This creates a dynamic and collaborative environment for sharing thoughts and refining concepts. Participants can also experiment with the chair's appearance using an interactive configurator. By simply touching one of the color cubes provided in the room, they can instantly change the chair's color, choosing from three available options. The color update happens in real time, allowing everyone in the meeting to see how the chair looks in each color variation, making it easier to decide on the most suitable design choice. The users are represented by a basic abstract avatar (i.e., a capsule). To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation.*

Insights from users

In this workshop, only 2 participants participated. However, valuable feedback was gathered and various feedback points were shared (see Table 6)

Theme	Description theme	User feedback	Suggested solutions
Immersion & realism	Sense of being in a real office	Appreciated gravity cubes, controller haptics, and ambient props; realism broken by inconsistent gravity or floating chair	Make gravity objects behave consistently, fix floating chair, improve lighting/visuals, and solidify wall/floor interactions
Movement & controls	User ability to navigate and interact	Frustration with controls, accidental teleportation, difficulty seeing controllers	Improve navigation UI, possibly integrate VR

			treadmill for freer movement
Customization & interactivity	Options for user interaction and design	Enjoyed color configurator; wanted more chair options and interactive props like magazines	Add more chair customization options; enable document sharing via Word/PowerPoint for productivity

Table 6: Overview general user feedback UC1.1 Professional Collaboration

The main themes in the Professional Collaboration UC were 'immersion & realism', 'movement & controls', and 'customization & interactivity'. First, participants appreciated the immersive and realistic aspects of the VE, especially the gravity effects of the 'gravity cubes'. They had mentioned that it was fun to play around with the 'gravity cubes' and expressed surprise as "*the boxes you could throw would actually fall*" (participant 2). There were also positive remarks for the small haptic feedback, such as controller vibrations, while drawing or moving which made their experience feel more realistic. Ambient props like magazines were also appreciated by the participants, as this enhanced the sense of being in a real office, the only remark being that it would have been nice to be able to interact with the magazines.

Furthermore, participants highlighted that seeing others in the VE made the experience feel more engaging and collaborative. Seeing where the other user was moving and hearing them made the experience feel more enjoyable and social, which participants said would be a huge plus in a work environment for effective and meaningful collaboration. However, there were some significant frustrations. Participants noted that at times the realism and control of the VE were inconsistent, which would break the immersion. Some of the things mentioned were that the 'gravity cubes' could be thrown through walls and that the design chair was floating, which caused a disconnect between the participants' expectations of how the virtual world would behave. It was also noted that at times it was difficult to navigate the environment with the controls, as sometimes the wrong buttons would be pushed as they could not see the controllers or the participants would accidentally teleport into walls, making them feel disoriented.

A broad range of improvements were suggested by the participants. A main improvement point was enhancing realism, especially the chair mechanics, so it can be manipulated like a real chair. Other improvement points of enhancing realism were to refine the visual design and lighting in the VE for greater depth, and to make the walls and floors behave as they would in real life. It was also mentioned that – although they generally liked the hand controllers to move around in the environment – they would have appreciated the ability to move around more freely in real life, this they suggested could be improved by adding the option to use a VR treadmill to more safely move about in the real world while in the experience. The participants also suggested adding additional customization options for different elements in the VE, e.g., to allow users to select various different chair styles and colors, as in a game interface, as well as integrating tools such as Word or PowerPoint to be able to share documents and files for more efficient collaboration.

Results UC1.2 Manufacturing training

<u>Description of the VR experience</u>

Inside the multi-user virtual environment of the manufacturing UC, two participants find themselves in an industrial scenario featuring machinery and workstations. They can approach a desk containing iron ingots, which can be picked up using the grab button on their VR controllers. Holding the ingot, they can move toward a large press machine, positioning the ingot correctly by simply releasing the grab button. To operate the press, participants can locate two red activation buttons on the left side of the machine, which need to be pressed simultaneously. This task can be performed alone or collaboratively with another participant, highlighting the multi-user capability of the experience where colleagues from different locations can join the same virtual room and interact in real-time. Once the press is activated, participants witness the machine in operation, transforming the ingot into a metal rod. They can then retrieve the finished rod, inspect it closely, share it with other participants, and place it wherever they choose within the virtual space. This process can be repeated to create multiple rods, allowing users to observe the consistency and changes in each manufactured item. Additionally, participants have the opportunity to explore how objects react under different gravity conditions, adding an educational layer to the experience as they observe the physical behaviors of materials in varied environments. The users are represented by a basic abstract avatar (i.e., a capsule). To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation.*

<u>Insights from users</u>

In these sessions, 8 participants participated. In Table 7, the main feedback points and themes can be consulted.

Theme	Description theme	User feedback	Suggested solutions
Immersion & safety	Feeling engaged and respectful of machinery	Users felt immersed and cautious around the virtual press; VR invoked realism and safety	No explicit suggestions here; feedback implied this aspect was functioning as intended
Physics & interactions	Consistency of object behavior	Objects couldn't be thrown naturally; some remained floating after release	Improve overall physics system to reflect realistic object behavior
Movement & navigation	Locomotion and interaction issues	Discomfort with teleportation and inconsistent joystick rotation; issues with object proximity during teleportation	Improve locomotion systems; allow more natural and continuous movement
Usability & onboarding	Instruction clarity for new users	Confusion among novice users; unclear what to do without help	Add progress bars, task lists, and clearer instructions
Collaboration	Multiplayer interaction	Users liked co-experiencing the environment; wanted more interactivity between users, like throwing and catching items	Expand multiplayer mechanics to allow shared object interaction

Table 7: Overview general user feedback UC1.2 Manufacturing Training

Across the interviews for the manufacturing training UC, participants generally found the experience immersive and engaging, there were some concerns about physics and interaction consistency, and there were suggestions to improve movement, usability, collaboration, and technical stability. According to several participants, they appreciated the immersion and engagement that the VR experience created. Although being a first basic version, participants said that it still gave them a feeling of being somewhere else. It was also noted that the simulated virtual press machine invoked caution, although they knew their virtual hands weren't real, they still respected the machinery, supporting the intention of the app for safety training. Participants also highlighted that they wanted to play around in the environment, suggesting that the elements of the VE successfully drew them in. For instance, several participants wanted to play around with the metal rods and they tried teleporting themselves as far as they could. Some participants were eager to explore what other elements in the VE they could interact with. A majority of participants also expressed appreciation for the user interactions in the experience, saying that it was fun to explore the VE with others and collaborating. For some participants, the user interactions were not only limited to collaborating on the task they were set out to do, but they were also playing around with each other, e.g., coming up with their own tasks and playing with the different objects.

However, there were also some frustrations among participants, especially in terms of inconsistent physics and interactions. Many were disappointed that they could not throw objects naturally or that the gravity of different objects and items didn't behave as expected. For instance, some participants had mentioned that some objects were grabbable but that they couldn't throw them, as the object would remain floating in the air as it was let go. Some participants also experienced challenges with movement and navigation. Here, the main pain point was regarding teleportation and the rotating view with a joystick. Participants mentioned that at times they found it annoying to teleport in the experience, as they had to aim close to objects to interact with them, but not too close as they would end up in the object otherwise. Thus, most participants said that they rather would have moved around physically themselves, but due to the inconsistency between the room sizes of the VE and the real world, some participants weren't so comfortable doing so. In terms of the rotating view with the joystick, some participants mentioned that the camera movement didn't feel realistic to them and rather disorienting, as it wasn't a continuous movement. Finally, several participants wished for a smoother onboarding and clearer instructions and the beginning of the experience, so that it's more clear what they have to do, especially for novel users, as some participants mentioned that they had never tried VR before and thus didn't know exactly what to do unless told. Some participants mentioned that they would have appreciated having a game-like task list popping up, or a progress bar to show how the task is going and what they have left to do.

Looking ahead, participants suggested some areas for improvement, especially in terms of physics and the multiplayer component. The main suggestion in terms of physics was to create a more consistent physics system so all objects feel and behave as they would in the real world, for example being able to throw items and if dropped they would fall to the ground and not float. It was also important to the participants to strengthen the multiplayer component. One participant had mentioned that as they were playing around with different objects, they would have liked to be able to throw the object to the other person for them to catch. This implies that these types of collaborative features would help make cooperative tasks feel more natural.

Results UC2.1 Health

Description of the VR experience

In this single-user version of the UC, participants are welcomed into a cozy, modern virtual room by a virtual IVA (dressed as a nurse). The room resembles a typical bedroom in an ordinary house. It features a desk with a computer, headphones, and a cushioned chair placed on a small rug. Floating shelves adorned with books, plants, and decor add a warm touch. A large white wardrobe provides storage, and a game controller suggests gaming as a hobby. The virtual nurse guides participants through the scenario, focusing on exploring the VE and interacting with a simple game. The game involves catching musical notes that visually emerge from a music box as music begins to play. Participants can move around, observe different elements of the room, and engage with the musical notes. In this version of the UC, the experience was limited to a single user, who was embodied as a basic non-human avatar in the form of a capsule. To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation.*

Insights from users

In these sessions, 11 participants participated. In Table 8, the main feedback points and themes can be consulted.

Theme	Description theme	User feedback	Suggested solutions
Immersion & calming effect	Environment's relaxing and engaging feel	Praised aesthetics, calming music, and immersive feel; useful distraction for medical anxiety	Suggested tailoring for longer procedures like cancer treatment where time allows
Engagement & personalization	Game challenge adaptability	Game might lose attention over time	Add difficulty levels or personalized tasks to maintain focus
Technical interactions	Ease of using controllers	Issues with pointing/selecting; some frustration	Refine controller responsiveness
Character design	Virtual guide character design	Avatar seen as silly or distracting	Make character less prominent or more serious
Practical integration	Use in healthcare settings	VR setup may not be practical for short visits	Adapt app for longer, scheduled treatments

Table 8: Overview general user feedback UC2.1 Health

Participants who tested the health app, gave quite positive feedback. Many were immediately struck by the immersive and calming virtual environment, praising the realism and vibrant aesthetics. Several mentioned that the app reminded them of a video game, remarking on its engaging colors and soothing background music. These features created a strong sense of presence, allowing them to feel immersed in the VE. This sense of immersion was especially valued by those who normally struggle with anxiety during medical procedures. Some participants noted that if they were getting their blood drawn or undergoing other unpleasant interventions, they could easily see themselves focusing on the VR scene rather than the procedure. Although they enjoyed the game, they also suggested that engagement could be increased with adjustable difficulty settings or other personalized tasks to help retain their attention. Without this, a few felt they might lose focus and return to thinking about the blood drawing procedure.

Although most participants appreciated the intuitive interactions and simple instructions in the app, some encountered technical challenges, especially with the VR controllers. Pointing and selecting options often took multiple attempts, creating frustration. The virtual guide character was noted as being distracting. Some had said that it looked silly or felt strange having someone with them in the room dancing in the corner. They suggested making the character less prominent or more serious to enhance the overall calming atmosphere. From a practical standpoint, participants with clinical experience themselves also pointed out challenges of integrating VR into busy healthcare environments. They noted that setup, maintenance, and charging requirements would take valuable time that frontline staff often do not have. Thus, using VR with every patient would be unrealistic, especially for shorter or routine visits. They suggested instead making the app suitable for longer procedures, such as cancer treatment. In sum, most participants reacted positively to the VR health app's immersive and distracting potential, especially as a calming tool for anxious patients.

Results UC2.2 Cultural Heritage

Description of the VR experience

In this single-user version of the UC, the participant, represented by a non-human avatar (a capsule), enters a VE titled "Breaking Out – Escape Helpers in Berlin." Upon entry, the participant selects their preferred language (German or English). An introductory audio begins playing alongside on-screen text, with historical photographs displayed on either side of the splash screen. To begin the experience, the participant clicks the "Start" button and navigates the environment using VR controllers. Movement is enabled through either smooth locomotion via joystick or teleportation to designated areas. The experience involves interacting with various objects to uncover a historical narrative. The participant first locates two headphones in the room, wears them, and listens to audio stories while viewing accompanying historical images. They then interact with a glowing shovel, digging through layers of dirt and stone to reveal a concealed tunnel entrance. As the storyline advances, a ringing phone directs the participant to replace a broken vacuum cleaner that powers a ventilation system. After finding and replacing the old vacuum with a new one, another call confirms the task's success. Following this, the participant sits on a swing that descends into an underground tunnel. Within the tunnel, they continue exploring, reconnect electrical wires to restore lighting, and crawl through tight spaces. Eventually, they reach the tunnel's end, sit on a second swing, and are lifted to the East side. Upon returning to the tunnel, they hear urgent voices warning of incoming police and ultimately escape to freedom, where a basic human avatar appears, signaling the end of the experience. To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation.*

Insights from users

In this workshop, 4 participants participated. In Table 9, the main feedback points and themes can be consulted.

Theme	Description theme	User feedback	Suggested solutions
Immersion & realism	Recreating historical settings	Environment praised for realism and engagement	None specifically suggested here, but tone implies good implementation
Controls & navigation	Movement and camera interaction	Confusing joystick controls; crawling/standing up induced cybersickness	Align controls with gaming norms; reduce or modify crawling elements
Interaction mechanics	Object manipulation realism	Shoveling dirt was unrealistic; swing mechanic unreliable	Improve shoveling realism and interaction reliability; allow manual swing control
Narrative clarity	Story engagement and coherence	Some felt lost in the storyline; love story lacked emotional depth	Add voiceovers, live guides, projections; more emotionally engaging narrative delivery (e.g., phone call from the lover)

Table 9: Overview general user feedback UC2.2 Cultural Heritage

Participants in the VR cultural heritage app workshops generally appreciated the immersive realism of the environment and the freedom to explore it at their own pace. One of the participants had visited the location in real life and was impressed by how well the VE had recreated the space in a realistic and engaging way. They also emphasized that this type of app is a great opportunity to make cultural heritage more attractive to the general public, and that it could be interesting in an educational setting, such as younger students or history students. Interactive elements that were especially enjoyable included being able to physically move around in the scene, picking up and throwing objects, the directional sound that added to the realism, as well as the fact that they were given concrete tasks to complete.

There were, however, some important critiques. Some participants struggled with the app's control scheme. They described that the camera and movement controls were confusing as these were opposite of what they are used to, noting that normally in gaming the left joystick is for running and the right is for the camera movement. It was also mentioned that although they enjoyed physically moving in the environment, the crawling and standing up repeatedly was at times disorienting and caused some of them to feel cybersickness. Several also commented that some features, such as the swing, didn't work reliably and that the mechanics of shoveling the dirt felt unrealistic as the dirt would disappear even if they made sweeping movements. Some suggestions for these interaction features included to make it possible for users to manually pull themselves up the swing, and to make the shoveling more realistic, as well as adding options to control how heavy the shoveling could be.

Comments were also made about the narrative and storyline of the experience. At times, participants felt lost about the story and its purpose. Especially for the love story, some felt that the context was unclear and that it felt underdeveloped and disconnected from the rest of the experience. To ensure a more coherent and dynamic experience, they suggested using voice overs, live guides, or visual projections to make the stories and content feel more real and emotionally engaging. An example of this was that there could be a phone call from the lover on the other side of the wall, making the love story a bit more central to the storyline for the users. In short, the workshops revealed a strong interest in this VR experience as an educational and engaging platform for cultural heritage.

3.2.4. UC validation round 2: V.0 PRESENCE app testing

The V.0 PRESENCE app built upon the First Playable App, incorporating the core technologies developed within WP2–4: Holoportation, Digital Touch, and Intelligent Virtual Humans. A tailored version of the V.0 app was created for each UC scenario. IMEC conducted end-user tests at the Cave at the FARI Institute in Brussels between the 19th – 22nd and 26th of May 2025. In the initial phase of testing, participants engaged with the VR experience across the four UC scenarios: Professional Collaboration (5 participants), Manufacturing Training (3 participants), Health (12 participants), and Cultural Heritage (3 internal user tests conducted by consortium member IMEC). Following the VR session, participants completed a survey from UHAM focused on user experience (UX) and presence evaluation. Afterwards, they participated in a semi-structured interview to further discuss and reflect on their experience.

Recruitment efforts were aimed towards students and personnel at the Vrije Universiteit Brussel, but also the general public.

Methodology

<u>Testing the app</u>

Four sessions were planned for this activity, one session per UC. Participants were invited to a 1-hour session to experience the V.0 PRESENCE app. In the first part of the session, participants got to try the VR experience (Figure 4), after which they answered the UX questionnaire of UHAM (See Section 3.3.4) .

Figure 4: User Evaluations V.0 PRESENCE app

Interview

After completing the survey, the participants took part in a semi-structured interview to further validate the UC and the experience. During the interviews, the researchers asked questions about first impressions as well as questions designed to encourage the participants to reflect further on interaction, navigation, UX, and social presence, as well as further improvements (see Adjuncts' section 8.3).

Analysis

The interviews were voice recorded and later transcribed with Scribewave. The transcripts were then analyzed in MAXQDA, with the help of their AI function to help explore themes and feedback points. The AI function was used to speed up the analysis process due to time constraints. All themes and feedback points were then verified by the researchers to mediate any misinterpretations or omissions.

Results UC1.1 Professional collaboration

Description of the VR experience

In the multi-user (2 users) professional collaboration UC, participants enter a virtual meeting room designed for brainstorming sessions. At the center of the space is a 3D model of an office chair, the focal point of the discussion, which participants can pick up, move, and examine from all angles. A whiteboard allows for real-time notetaking and sketching, supporting collaborative idea sharing. Additionally, participants can interact with a color configurator (boxes) to change the chair's appearance. By selecting from available color cubes, the chair's color updates instantly, allowing all users to evaluate design options together. To enhance interaction, participants will wear haptic gloves that provide tactile feedback, such as pressure sensations, when grabbing or holding virtual objects, adding a layer of realism to the experience. For participant representation within the virtual environment, one user is holoported, enabling them and other users to see a live representation of themselves in the space. This adds a sense of presence and embodiment to the collaboration. The other user is represented as a basic non-human avatar (a capsule). To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation.*

Insights from users

In these sessions, 5 participants participated. In Table 10, the main feedback points and themes can be consulted.

Theme	Description theme	User feedback	Suggested solutions
Ease of use & intuitiveness	Ease of navigation and object interaction	Appreciation for hand controller navigation and object interaction with hand controllers	Good implementation, so no suggestions for improvement
Haptic gloves (WP3)	Navigation issues, performance and comfort of haptic gloves	Heavy gloves, inconsistent gesture control for navigation	Make gloves lighter and more ergonomical, improve gesture controls and interaction cues
Holoportation (WP2)	Quality and realism of holoported avatars	Pixelation, disconnection due to headset use	Enhance resolution and remove headset barrier
Avatar representations	Glitches in avatar representations	The holoported user had an additional basic avatar representation, causing confusion	Ensure one avatar representation per user
General improvements	Increased immersion	Co-creation and interaction options; Structured activities; Enhance audio-visual fidelity	Add several objects to co-create and interact with; Add more structured activities to be completed; Ensure users can hear each other, introduce headphones to reduce external noise

Table 10: Overview general user feedback UC1.1 Professional Collaboration

In the evaluation of the UC1.1 VE we found both positive remarks and areas for improvement. Here, participants appreciated the natural navigation with the hand controllers and ability to interact with virtual objects, such as the pen and the whiteboard. However, participants also faced some issues, some participants experienced glitches such as getting stuck in walls or seeing two avatar representations for one user, and others described that the haptic glove was difficult to use, as the gesture controls were at times imprecise and the interactions were not always working. Other participants noted that the navigation sometimes lacked consistency, and suggested that providing clearer instructions or interaction cues could improve the experience. Main suggestions for improvement included to introduce more engaging and creative tasks to really encourage collaboration, and to better customize the environment to match familiar workspaces or company identity, improve holoported avatar representations to make them feel more present to the other user (as the holoported user was wearing a headset, the other user felt disconnected from them), and enhance the audio-visual fidelity to support immersion such as ensuring that users better can hear each other e.g., by introducing noise cancelling headphones to remove external disturbances/noises and to add volume settings.

In the evaluation of the technical pillars, we saw mixed experiences. Regarding the evaluation of the haptic gloves, participants mentioned that they felt heavy and difficult to use, especially for gestures such as pointing or making a fist, as the action in the real world would not be accurately translated in the virtual world. We tried to mitigate this by recalibrating the gloves with each user, and as soon as issues occurred, we redid the process, but sometimes the issues remained. Participants also mentioned that the haptic feedback from the gloves was at times random, which caused confusion and reduced their feeling of control. Some suggestions for improvement included making the gloves lighter and more ergonomic to use, as well as making it better suited for different hand sizes to reduce exclusion and friction in use. Regarding the evaluation of the holoportation, participants were generally impressed by the visual quality of the holoported avatar, and they believed that as its fully functional, it would definitely enhance realism and presence for users. However, some participants mentioned that the holoported avatar was often quite pixelated and blurry, and that due to the holoported user also wearing a Head Mounted Display (HMD), the participants who functioned as 'the other user' felt disconnected from them and that this had an impact on their feeling of presence. It was mentioned that during the sessions where the participants could hear each other, they felt as though this made up for the visual aspects, and this way they could still interact and collaborate with each other.

Some general feedback points regarding thresholds and opportunities of the V.0 PRESENCE app also surfaced during the sessions. Regarding thresholds, participants mainly pointed to the intuitiveness and usability of the app and technology. Participants described that since the haptic gloves were more difficult to use than the hand-held controllers, they felt that this created a barrier to complete tasks in the virtual environment. Due to physical discomfort and at times technical malfunctions, participants highlighted that this could significantly lower the threshold for effective usage. Other participants also noted that some actions with objects failed or malfunctioned, disrupting their sense of immersion. Regarding opportunities, participants saw great potential for shared creative tasks within VR and gave a broad range of suggestions to further improve the experience. These suggestions included enabling users to co-create several objects and be able to interact with more objects (such as sitting down by the meeting table to discuss the design), adding more structured activities for users to complete (such as drawing together or complete tasks and/or challenges), and improving audio- and visual quality to reinforce the sense of presence and connection between users.

Results UC1.2 Manufacturing training

<u>Description of the VR experience</u>

In the multi-user (2 users) virtual industrial scenario, participants enter a realistic workspace equipped with machinery and workstations. The core task involves operating a press machine to transform iron ingots into metal rods, following a specific step-by-step procedure. Participants begin by opening the press door and placing an ingot inside. They then exit the press area, close the door, and activate the machine by pressing two red buttons simultaneously, either on their own or in coordination with another participant, highlighting the multi-user capabilities of the experience. Once the ingot is processed into a metal bar, participants open the door, remove the finished bar from the area, and can repeat the operation from the beginning. To enhance realism, participants wear haptic gloves that provide tactile feedback, such as pressure sensations, when grabbing or holding virtual objects, creating an immersive, hands-on experience. The scenario also allows users to experiment with different gravity settings, adding an educational layer as they observe how materials behave under varied environmental conditions. For participant representation, one user is holoported into the virtual space, appearing as a live embodiment of themselves. The other user is represented by a basic non-human avatar, depicted as a capsule. To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation.*

Insights from users

In these sessions, 3 participants participated. In Table 11, the main feedback points and themes can be consulted.

Theme	Description theme	User feedback	Suggested solutions
Environment design	Design and layout of the VR warehouse model	Easier to navigate than previous version; some found it overly simplistic with only basic shapes	Add more complex virtual objects and components (e.g., handles, tools, machinery) to reflect real-world scenarios
Navigation & movement	Ways users move through the environment	Mixed feedback: teleportation and gaze appreciated; lack of free movement and cable tethering seen as limiting; joystick control unintuitive	Explore wireless/standalone options; revise control scheme (e.g., use left joystick for movement); keep intuitive navigation methods
Haptic gloves (WP3)	Use of gloves for natural gesture interaction	Potential for realism appreciated; issues with bulkiness, unclear feedback, and object release problems	Reduce glove bulk; improve haptic feedback clarity and gesture accuracy; enhance glove integration into interactions
Virtual Interactions	How users interact with virtual objects	Some interactions unnatural (objects "jumping"); throwing improved; collaborative features lacking	Improve physical realism of interactions; add collaborative mechanics (e.g., multi-user tasks)

Holoportation (WP2)	Live representation of remote users in VR	Gesture recognition enhanced immersion; issues with directionality and unclear presence reduced social immersion	Fix alignment issues; improve photorealism and user orientation for stronger presence
Intelligent Virtual Human (IVH)	Virtual character representation	Acknowledged but not interactable; visual liked; potential seen	Enable user interaction with IVH; possibly use realistic avatars for users when haptics isn't available
Basic avatar representation	Visuals used to depict users in the virtual space	Basic avatars praised for simplicity and charm; sufficient for immersion	More realistic avatars could help immersion when haptic feedback is missing

Table 11: Overview general user feedback UC1.2 Manufacturing Training

In the evaluation of the manufacturing training environment, some participants noted that compared to the first playable app version, the new warehouse model had a more manageable size, making it easier to navigate in the environment and to not get distracted by other elements not relevant to the experience itself. However, some described the environment as overly simplistic, as the interactions were limited to basic shapes like cubes. Here, they suggested expanding the range of virtual objects and tasks to include more complex components such as handles, tools, or machinery elements, which would better reflect real-world scenarios.

While some appreciated the navigation methods, such as teleportation, rotation, and gaze-based movement – which allowed them to explore the space without excessive effort – others indicated that they thought it was annoying not being able to move around themselves. It was suggested that to mitigate the physical tethering of the system – where cable length was seen as restricting natural movement – options such as stand-alone or wireless options should be explored. When using the hand controller, they had also indicated that it was strange that the left joystick was used for camera movement, as normally it's used for character movement in other gaming contexts. The use of the haptic gloves for navigation was generally appreciated as the ability to use natural gestures rather than relying on traditional button-based controllers made the interaction feel more aligned with real-world movements. Participants also highlighted the immersive world as a useful sandbox environment for early testing of training scenarios.

In terms of virtual interactions, it was noted that some virtual interactions felt unnatural. For instance, objects would "jump" into place rather than responding to the user's input in a physically realistic way. This detracted from the sense of realism, which is particularly important in a manufacturing context where tactile accuracy and interaction precision are key. Some mentioned that although the object interaction features at times left room for improvement, the throwing mechanic had improved since the first playable app version. Suggestions were also made to introduce collaborative mechanics, for example, having multiple users coordinate actions like pressing buttons simultaneously, thereby integrating teamwork and supervision elements into training sessions.

When evaluating the haptic gloves, experiences were mixed. Participants acknowledged the potential of the gloves to translate real-world gestures into the VE and saw them as a promising tool for fine-motor interaction tasks. However, several participants noted that the gloves felt bulky and somewhat heavy, especially on the fingers, which impacted comfort and prolonged use. Another common challenge was the lack of clear feedback from the haptic system, users were unsure how much force to apply or how precisely their gestures were being registered. For some interactions with the gloves, such as grabbing items, the glove would get stuck and the object could not be released. These issues created a barrier to fluid interaction and reduced the sense of control. Suggested improvements included reducing the glove's bulk to enhance comfort, refining the haptic feedback to provide clearer, more consistent cues, particularly in tasks requiring force sensitivity or accuracy, and to integrate haptic functionality more seamlessly with the overall interaction design.

In terms of holoportation, participants were generally impressed by the technology's ability to convey non-verbal cues and body language, which they felt added significantly to the sense of presence and interpersonal connection. Simple gestures such as waving were described as making the interaction feel notably more immersive. However, it was noted that as the holoported user was also wearing a HMD, it wasn't clear to other participants whether that user was 'present' with them. The holoported representation was also facing another direction from the other users, although the person being holoported reported that they were facing them. This inconsistency had a huge impact on the perceived social presence and immersion, as participants felt detached from each other. Some speculated that aside from addressing these issues, combining holoportation with more photorealistic virtual environments could further enhance the overall realism and training relevance of the system.

Present in the environment was also an intelligent virtual human, although the participants were not yet able to interact with it. Participants acknowledged the IVH but proceeded with the given tasks together with the other user present with them in the experience without further comment. Some had mentioned when asked about the IVH that they liked its representation and that it's a good foundation to build further on, but that they would have enjoyed being able to interact with it. The basic avatar representation of users had also received praise, as it was deemed charming in its simplicity. It was mentioned that this representation of users would be enough to still feel immersed in the environment, as they know they're talking and interacting with another person, but that if they would not have the haptics at hand, then making more realistic avatars (such as the IVA but for actual users) would be beneficial for increased immersion.

Regarding thresholds and opportunities for the V.0 PRESENCE app within the manufacturing training context, a few clear themes emerged. On the threshold side, physical limitations, such as the weight of the gloves and the presence of cables, were seen as potential barriers to adoption, especially in scenarios requiring extended use or dynamic movement. Moreover, limitations in the realism of interactions could hinder training effectiveness, particularly for tasks where precision and physical fidelity are critical. On the opportunity side, participants saw great value in the app's potential for immersive, gesture-driven training and remote collaboration. They noted that the system could be especially effective for simulating manufacturing workflows, fostering team-based coordination, and enabling supervisor-led virtual sessions using holoportation. These insights suggest that with targeted improvements in realism, ergonomics, and collaborative design, the V.0 PRESENCE app could play a valuable role in next-generation manufacturing training solutions.

Results UC2.1 Health

Description of the VR experience

In this multi-user (2 users) UC, participants are welcomed by an avatar (IVA) into a cozy, modern virtual room that resembles a typical bedroom. The space features familiar elements such as a desk with a computer, headphones, a cushioned chair, a rug, floating shelves with books and decor, a ring light, a wardrobe, and a game controller, suggesting everyday activities like studying, recording, or gaming. The avatar guides participants through the environment and introduces a simple game: catching musical notes that emerge from a music box as music plays. Participant A (representing the patient and embodied a basic non-human avatar) wears a haptic glove and vest that deliver tactile and physical feedback, such as pressure sensations when "holding" an object or calming vibrations to aid in regulated breathing, enhancing the sense of immersion during the game. Meanwhile, Participant B (representing the visitor) is embodied as a human-like avatar and can interact with Participant A, fostering a shared, co-present experience. Guidance through the environment is provided by a rudimentary version of an Intelligent Virtual Agent (IVA), which explains each step of the interaction. To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation.*

Insights from users

In these sessions, 12 participants participated. In Table 12, the main feedback points and themes can be consulted.

Theme	Description theme	User feedback	Suggested solutions
Environment design	Quality and realism of the virtual environment	Experience often felt disjointed or unrealistic; environment sometimes appeared cartoonish or childlike; mismatch with patient demographics; sometimes calming, but lacking engagement or presence	Design environments to match user demographics; create either fully realistic or fully fantastical settings; include calming elements like forest views; avoid overly realistic medical tools if triggering; add continuous music for smoother transitions
Avatar realism	Realistic representation of avatars	Avatars too abstract or non-human; patient capsule avatars lacked emotional connection; visitor avatars lacked realism, eye contact, and natural movement; some agent behaviors were awkward or stress-inducing	Make patient avatars more human-like; improve realism of visitor avatars with gaze, gestures, and movement mechanics; simplify or improve behavior of Intelligent Virtual Agents (IVAs); allow customization based on context (e.g., abstract avatars in some UCs)

Haptic gloves (WP3)	Use of gloves for tactile interaction and immersion	Positive view on potential; gloves mirrored hand movements well but felt cumbersome and lacked fingertip sensors; limited realism in touch simulation	Improve comfort and fit; add responsive fingertip sensors; enhance haptic feedback precision
Haptic vest (WP3)	Use of vest for bodily feedback and sensory immersion	Mixed reactions; added sensory layer but often unclear or not action-related; bulky and uncomfortable for long use	Make vest feedback context-aware and responsive; increase comfort through better ergonomics and fit
Intelligent virtual agents (WP4)	Human-like digital assistants and their interaction quality	Often stiff, unnatural, or stress-inducing; limited conversational ability; awkward movement	Improve naturalness and responsiveness; consider simplifying or abstracting design to reduce emotional strain
Emotional & therapeutic potential	Use in emotional support, pain relief, therapy	Seen as promising for remote visitation, emotional support, and exposure therapy; calming and distraction effects were noted	Incorporate music, soft visuals, and gentle tactile input; develop tailored environments for emotional regulation and therapy (e.g., phobia exposure)

Table 12: Overview general user feedback UC2.1 Health

In the health UC, key themes centered around the importance of immersion quality, emotional comfort, and the realism of both environment and avatars to support meaningful patient interactions. Across participants, the technology was seen as having promising applications for remote visitation, emotional support, and exposure therapy, but only if certain usability and design thresholds are addressed.

In the evaluation of the VE, participants shared a range of experiences. Several noted that while visual fidelity in some instances was advanced and the navigation tools (such as teleportation and gaze) were generally functional, the overall immersive experience was often described as disjointed or insufficiently realistic. For example, participants expected the content and design of the VE to match patient demographics. Some had mentioned that although they generally felt calm and distracted, it resembled too much of a child's room, and some even thought the experience was intended for children only due to this. The setting had also appeared too cartoonish or unfamiliar to some, which created a barrier to emotional engagement or a sense of presence. Others noted that the environment did not resemble a real hospital and could even induce discomfort when elements like medical tools or nurse avatars were overly lifelike or poorly integrated. Preferences for how the VE should be designed varied, but included a more realistic hospital atmosphere, a more adult design if intended for adults, adding more calming elements such as a window overlooking a forest, and more abstract or game-like environments to reduce stress and increase comfort. Suggestions for improvement included designing environments that are either fully fantastical or highly realistic (but familiar), ensuring smoother transitions (such as continuous background music), and carefully avoiding triggers like needles when possible.

In terms of interaction, participants consistently emphasized the need for intuitive and natural controls. Finger-based gestures and realistic hand tracking were appreciated, especially when they allowed for navigation or pointing. However, limited interactivity with virtual objects, abrupt transitions, or lack of feedback often diminished engagement. A more seamless and consistent interaction experience was recommended to improve the sense of agency and control during the session.

The evaluation of the haptic gloves revealed both enthusiasm and areas for refinement. Participants generally responded positively to the potential of gloves to enhance immersion and enable more direct, embodied interaction with the virtual environment. The visual mirroring of hand movements contributed positively to presence. However, the gloves were also described as cumbersome, especially without tactile sensors at the fingertips, which limited their effectiveness in simulating touch. Suggested improvements included increasing comfort, making the gloves easier to use, and integrating more precise and responsive haptic feedback, particularly at the finger level.

Regarding the haptic vest, reactions were mixed. On the one hand, it provided an additional sensory channel that could reinforce the immersive experience; on the other, the vibration feedback was often perceived as unclear or not directly tied to user actions. In some cases, the vest felt bulky or awkward to wear, raising concerns about comfort during extended use. Participants recommended making the vest more responsive and context-aware, adjusting the feedback to reflect in-world actions more precisely, and improving physical comfort through better fit and flexibility.

The avatars used to represent patients and visitors also played a critical role in shaping the experience. The “capsule” form of the patient avatar was generally seen as too abstract or non-human, which created a disconnect and made interactions feel unnatural or emotionally distant. While some participants suggested making the patient avatar more human-like, such as showing a realistic figure in a bed or chair, to improve relatability and presence, others indicated that the basic avatar could be beneficial in cases where advanced avatar customization options are not available. The visitor avatars were appreciated for their potential to convey presence, especially when they mirrored familiar figures like friends or family members. However, lack of eye contact or body orientation, and general low realism, made the interaction feel one-sided or confusing. Some had even mentioned that the movement mechanics of the visitor avatar felt strange and unrealistic, as they would teleport from one point to another. To enhance this, participants suggested making visitor avatars more lifelike, enabling more non-verbal cues like gaze and gestures, and integrating more realistic movement mechanics.

IVAs were another area of feedback. While their visual realism was sometimes praised, the interactions themselves were often found lacking. Some participants described the agents as stiff or unnatural, with limited conversational capabilities or awkward behaviors (e.g., standing still and “moving weirdly”). For others, the presence of a human-like IVA, even one intended as a helpful nurse, caused stress or discomfort, especially when the interaction felt forced or overly realistic. Recommendations included improving the naturalness and responsiveness of these agents where desired, or in some cases, intentionally abstracting or simplifying them to reduce emotional strain.

When considering thresholds for effective use in health contexts, participants emphasized ease of use, emotional comfort, and a strong alignment between the virtual and real world. Participants with heightened sensitivity to medical environments noted that mismatches in realism could reduce the effectiveness of VR-based interventions. Physical comfort and accessibility were also cited as essential, hardware like gloves and vests must be lightweight, ergonomic, and unobtrusive to ensure that the system is usable by a wide range of patients. At the same time, the need for natural, intuitive interaction was consistently highlighted as a baseline requirement.

Despite these challenges, the sessions also revealed several key opportunities. Participants saw the potential for the V.0 PRESENCE app to facilitate remote patient-visitation scenarios, providing meaningful social connection in healthcare settings. Others noted the calming and therapeutic potential of the environment when paired with music, soft visuals, or gentle tactile input. Some envisioned the technology supporting pain management or emotional regulation during treatment. In addition, the possibility of using tailored environments for exposure therapy, such as for patients with medical phobias, was mentioned as a powerful direction for future development.

Together, these insights suggest that with enhancements to immersion, realism, and interaction quality, alongside improvements to the comfort and responsiveness of physical hardware, the V.0 PRESENCE app holds meaningful potential to support emotional well-being and social connection in health-related contexts.

Results UC2.2 Cultural heritage

Description of the VR experience

In the single-user cultural heritage UC, participants enter the immersive virtual experience "Breaking Out – Escape Helpers in Berlin", selecting either German or English upon entry. An introductory audio plays alongside historical photos and on-screen text. Once they click "Start," participants explore the space using physical movement or VR controllers, with the option of smooth locomotion or teleportation. The experience guides participants through a series of interactive tasks that unfold a historical escape narrative. They begin by listening to audio stories through virtual headphones while viewing related photos, then use a glowing shovel to dig through dirt and reveal a hidden tunnel. Following a ringing phone call, they receive instructions to replace a broken vacuum cleaner, which they find, disconnect, and replace to restore the tunnel's ventilation system. After another phone confirmation, they sit on a swing and descend into the underground tunnel. In the tunnel, participants reconnect electrical wires, crawl through narrow spaces, and eventually reach the East side via a second swing. The experience concludes with a dramatic escape, welcomed by an avatar, marking the end of the participant's journey to freedom. To enhance interaction and immersion, participants wear haptic gloves and a haptic vest. The gloves simulate tactile sensations like pressure and vibrations when handling virtual objects, while the vest enhances embodiment, such as simulating the physical sensation of crawling through the tunnel. To see what the virtual environment looks like, please consult deliverable D5.2 *Integration and Demonstration II - Intermediate integration, testing and validation*

Insights from users

For the cultural heritage UC, in the testing round initially planned, we experienced some technical issues that hindered the involvement of end-users external to the project. These issues mainly concerned interaction features while using the hardware and issues within the experience itself:

- Interaction via the haptic gloves through hand movements (thumbs up, pinching) was not working consistently, causing a loss of time to get the application started
- Spawning issues within the UC environment
- Starting in the middle of the tunnel, rather than at the beginning of the experience

Due to the time constraints for the tests (1 hour per participant) these issues caused too much delay in testing the actual experience on the foreseen day. However, the Zaubar team worked to resolve them, which allowed us to plan an additional testing round with 3 internal testers (users involved in the PRESENCE project but not in the technical WPs). These internal testers, like the end-users, had different levels of experience with XR.

These internal tests with internal users showed that the concept of the experience is engaging, and that the app shows great potential for an immersive exploration of cultural heritage content in a virtual setting. The main feedback from the internal tests revolved mainly around usability issues faced in terms of interaction mechanics with the use of the haptic glove, as described below.

The tapping gesture, which was used for selection, wasn't always recognized reliably. Even though the gloves were calibrated for each person, there were moments when the tapping gesture was mistakenly interpreted as a teleportation input. This led to some confusion and frustration, as testers had to teleport back and forth unintentionally. As the aiming line for selection was slightly above the virtual hand, it took some time to understand how this aiming mechanism worked. Pressing buttons using the tapping gesture was somewhat inconsistent as the haptic gloves would not always recognize the gesture, causing frustration among testers. This slowed down the flow of the experience, as longer time was spent just trying to trigger simple actions, such as pressing the button to use the swing and interacting with the photo information icons in front of the tunnel. It was also noted that picking up certain objects, like the shovel or the headphones, was difficult if these were dropped, as the system didn't always register the grab gesture correctly. Other tasks, such as using the swing or connecting cables in the tunnel, were also tricky, likely due to the gloves not registering movements accurately or due to limited interaction affordances. All these interaction bugs unfortunately disrupted the sense of ease and immersion.

Despite these issues, the design of the UC environment and the tasks in themselves were engaging and interesting. These early tests confirmed that the experience has a strong conceptual foundation but would benefit from targeted improvements to interaction reliability. Refining gesture recognition (to better differentiate between tapping and teleportation), improving the responsiveness of key interactions like button pressing and object grabbing, and adjusting affordances in complex tasks would all help streamline the experience. In addition, including a tutorial where users can practice how to teleport and interact with the haptic gloves. With these enhancements, the application could offer a much smoother and more intuitive way for users to engage with cultural heritage content in a virtual setting.

3.2.5. Lessons learned for Phase III

User requirement prioritisation proved challenging due to the amount of requirements that needed to be assessed by consortium members. Here, close collaboration with WP5, UC partners and technical pillars was necessary to follow-up closely. As the updating and prioritising of the user requirements is a time-consuming task that will continue within the next project phase, more structural continuous follow-up will be set-up during WP1 and WP5 meetings.

The user tests conducted with the First Playable app and V.0 PRESENCE app across the four UCs provided several key lessons that will inform future development and setup of user tests. A central takeaway was the importance of earlier and deeper integration of the technical pillars before involving users in testing. To ensure a smoother and more coherent user experience, earlier coordination between technical WPs and WP5 would be beneficial. Here, clear communication and coordination between WP5, technical WPs, and WP1 regarding testing timelines and delivery deadlines are also essential. By establishing a shared delivery timeline, sufficient time would be ensured for internal development testing, WP1 would have time to validate the technology before user sessions, and there would be adequate time for fixes or adjustments if needed. This approach would also allow researchers to plan for potential delays and troubleshooting by incorporating buffer time into the research schedule. Another lesson concerned the need for improved onboarding and guidance for participants, especially for those with limited knowledge and experience of using XR technologies. More structured introductions, embedded tutorials, and/or guided task flows – developed collaboratively between WP5 and UC partners, with input from WP1 – could enhance user confidence and reduce confusion during testing.

3.3. User Centric Approach & User Testing

Several UX evaluations have been performed during the second phase of the project as part of WP4 and WP1, involving two main user groups: developers and end-users. In the study conducted by UHAM, developers used the IVH PRESENCE Software Development Kits (SDKs), to create XR applications and provided feedback on their experience with the SDK. In the studies conducted by IMEC, end-users evaluated the applications developed within the project (the First Playable app and the V.0 PRESENCE app), focusing on usability and the sense of presence. Table 13 summarizes the evaluations performed with both groups.

3.3.1. Methodology

For these studies, UHAM developed standardized UX surveys – one for developers to evaluate the UX of the developed SDKs and one for end-users to evaluate the project applications and SDKs. These were shared with project partners in January 2025 to be used in their UX studies, and have since been revised and redistributed, along with documentation on the underlying scientific measures for context as well as the offer to assist and collaborate on studies of the other partners.

The surveys developed include both quantitative and qualitative methods, and cover both aspects of UX and the sense of presence. UX was measured by using different questionnaires such as the System Usability Scale (SUS), AttrakDiff, Extended Technology Acceptance Model (TAM2), and User Experience Questionnaire (UEQ). Open-ended questions complemented the standardized questionnaires to capture more nuanced feedback on opinions on the users' experience. Details of the surveys used for evaluating the IVH SDK, the First Playable apps, and the V.0 PRESENCE apps are provided in the Adjuncts' Section 8.4 and 8.5.

Only results relevant to UX and sense of presence are included in this deliverable, and a more comprehensive description of methods and results is presented in the sections of each study.

Nr.	Short Title	Target Group	Number of Participants	Measures
1	IVH SDK v0.1 evaluation	Developers	4	SUS, AttrakDiff, TAM2, open-ended questions
9	First Playable app evaluation	End users	23	SUS, AttrakDiff, TAM2, social presence questionnaire, IPQ, open-ended questions
10	V.0 PRESENCE app evaluation	End users	18	SUS, AttrakDiff, TAM2, social presence questionnaire, IPQ, open-ended questions
Total number of participants			45	

Table 13: Summary of UX (and sense of presence) studies

3.3.2. IVH SDK V0.1 evaluation

An early version of the IVH SDK (v0.1), which included a single virtual humanoid model (T4.1) and speech interaction (T4.3), was provided to Computer Science students at UHAM. These students used the SDK to develop Unity-based IVH applications as part of their Master's project, each addressing a specific research question and followed by empirical evaluation.

The **objective** of this evaluation was to gather early-stage UX feedback from developer users and inform iterative improvements to the SDK. Key results from this evaluation have also been published in [Ref. 4].

Quantitative results

<u>SUS</u>

The participants' responses to this questionnaire gave us an average SUS score of 56.88 (SD=6.88), indicating marginal usability in the ‘OK to Good’ range.

<u>AttrakDiff</u>

The AttrakDiff consists of 28 items grouped into four subscales: Pragmatic Quality (PQ), Hedonic Quality relating to Identity (HQ-I), Hedonic Quality concerning Stimulation (HQ-S), and overall Attractiveness (ATT).

The results show neutral to positive evaluations across all subscales:

- PQ (M= .89, SD=.69)
- HQ-I (M= .71, SD=.57)
- HQ-S (M= .39, SD=.47)
- ATT (M= .46, SD= .36)

TAM2

In this study, five subscales of TAM2 were used to measure **Intention to Use**, **Perceived Usefulness**, **Perceived Ease of Use**, **Output Quality** (e.g., "The quality of the output I get from the system is high."), and **Result Demonstrability** (e.g., "I have no difficulty telling others about the results of using the system.").

The evaluation of all scales was neutral to positive:

- Intention to Use (M= 4.5, SD= 1.41)
- Perceived Usefulness (M=4.81, SD= 1.28)
- Perceived Ease of Use (M=4.88, SD=1.15)
- Output Quality (M= 4.5, SD=.76)
- Result Demonstrability (M= 4.44, SD=1.26)

Qualitative results (open-ended questions)

Several open-ended questions were asked to capture more nuanced feedback on opinions on the use of the SDK. The first question asked about their general experience with the SDK. Several students noted using the SDK in both Master's and Bachelor's projects and expressed overall satisfaction. Another user had responded that "The intelligent virtual agent is currently missing some controls, such as the left arm up and down, which is a little frustrating, but otherwise, it's easy to use".

The next question asked which part of the toolkit they liked or disliked. Positive comments included "fundamental functionality works well" and appreciation for the flexibility of the toolkit. Reported issues included limited speech recognition reliability and missing animation controls. Some had indicated that they would have appreciated "more models", "more styles, hair, clothes for the avatar", and "higher usability when animating and building objects". There were no responses regarding the question on what they wish to be removed or changed about the toolkit.

Three users indicated that they would use the SDK again, with two stating they would recommend it to others – one noting this would depend on the specific UC. Another user indicated "yes and no" (maybe) to this question.

3.3.3. PRESENCE First Playable app evaluation

As mentioned in Section 3.2.3, participants filled out a UX-related questionnaire after testing the PRESENCE first playable apps (See Adjuncts' section 8.5). This section will report on the full results of these questionnaires.

Participant Demographic

23 participants (13 female, 10 male) with an average age of 24.96 (SD=6.28) from Belgium (22 from Brussels and 1 from Antwerp) took part in this study. Participants were asked to indicate previous experience with XR (VR and Augmented Reality (AR)) on an 11-point Likert scale. Unfortunately, the labels on both sides of this question were incorrect, as instead of XR they referred to the experience with Unity (i.e., 1=I have never used Unity before, 11=I am a Unity expert). Therefore, the labels were corrected after the study for future use of this online survey (1=I have never used XR before, 11=I am an XR expert). With these descriptions, the question resulted in an average

score of 3.52 (SD=2.45) meaning that a majority of participants did not have extensive experience with XR. Participants were also asked which PRESENCE application they used. As this was a multiple-choice question, participants could select multiple items. The results show that 4 participants used the Professional Collaboration UC application, 5 participants used the Manufacturing Training UC application, 9 participants used the Health UC application, and 4 participants used the Cultural Heritage UC application. Although some participants indicated that they used IVA (N=2), and Digital Touch (N=2) this is not the case, as these technical pillars had not been integrated in the First Playable App. Given that 22 participants reported using an application, but 23 participants completed the survey, it is likely that one participant selected a technical pillar instead of an application, as both were listed as options in the same question.

Quantitative results

SUS

The average SUS score of all PRESENCE applications used was 75 (SD=13.82). This indicates Good usability of the application, which also shows that the application was acceptable to users.

AttrakDiff

As mentioned in previous sections under this chapter, the AttrakDiff items are grouped into four subscales: Pragmatic Quality (PQ), Hedonic Quality relating to Identity (HQ-I), Hedonic Quality concerning Stimulation (HQ-S), and overall Attractiveness (ATT). The results (see Figure 5) show neutral to positive evaluations for all four subscales: Pragmatic Quality (M= 1.12, SD=0.92), Hedonic Quality-Identity (M= 0.19, SD=0.69), Hedonic Quality-Stimulation (M= 0.68, SD=0.96), and Attractiveness (M= 1.12, SD= 0.79).

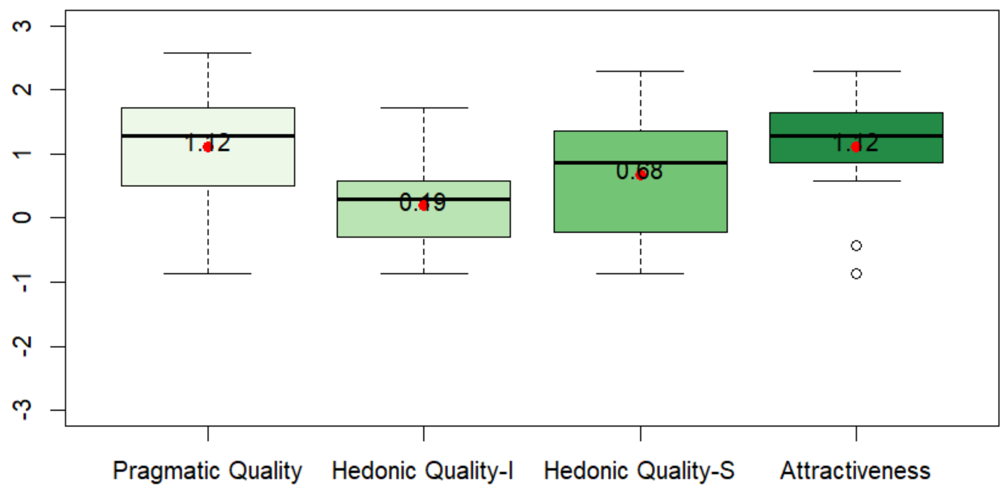


Figure 5: The results of the AttrakDiff questionnaire

IPQ

As mentioned in earlier sections under this chapter, the IPQ has 14 items for measuring the sense of presence experienced in a virtual environment, divided into 4 subgroups: General Sense of Being There, Spatial Presence, Involvement, and Experienced Realism. The rating uses a 7-point Likert scale (0–6) with varying anchors: some range from Fully Disagree to Fully Agree, while others use specific terms like Did not feel present to Felt present. The results (see Figure 6) for the subscales as well as the total sense of presence were as following:

- General Sense of Being There (M=4.26, SD=1.39)
- Spatial Presence (M=4.35, SD=1.03)
- Involvement (M=3.16, SD=1.51)
- Experienced Realism (M=1.98, SD=1.01)

Total sense of presence (M=3.33, SD=0.99) These results indicate that while the general sense of being there and spatial presence were very high, the involvement and total sense of presence were moderately rated. The experienced realism is rated the least and therefore needs to be improved.

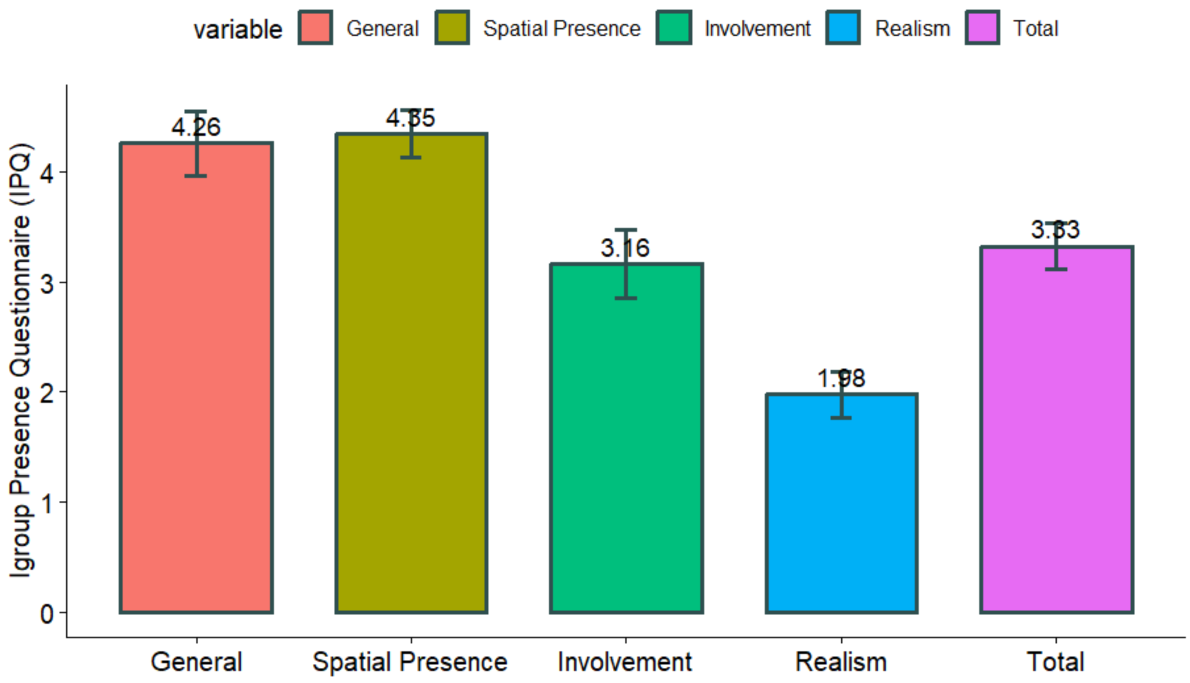


Figure 6: Results of the IPQ for the first playable app evaluation

<u>Social Presence Questionnaire</u>

The items of the Social Presence Questionnaire could be answered using a 7-point Likert scale (1=fully disagree to 7=fully agree). To evaluate the perceived social presence, item 3 (*The thought that the person is/was not a real person crosses my mind often*) and item 5 (*I perceive/perceived the person as being only a computerized image, not as a real person*) of the questionnaire were reverse coded by reducing 8 from the original values, as these items were formulated negatively. To bring the scores on a scale of -3 to +3, all answers were subtracted by 4. After that, the means of these items per participant, and for all participants, were calculated. The results showed a neutral evaluation of social presence (M=0.02, SD=1.3), on a scale from -3 to +3.

<u>TAM2</u>

The first 3 subscales of TAM2 were used for this evaluation (Intention to Use, Perceived Usefulness, and Perceived Ease of Use). The results (Figure 7) show moderate to very high evaluations:

Intention to Use (M=5.15, SD=1.16), Perceived Usefulness (M=4.38, SD=1.36), and Perceived Ease of Use (M=6.10, SD=1.11).

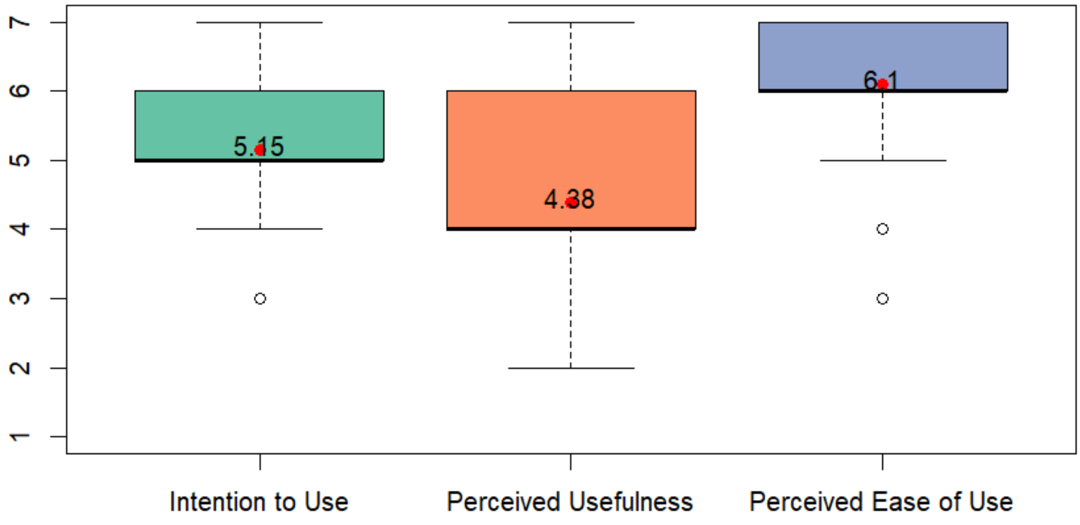


Figure 7: The results of the TAM2 questionnaire

3.3.4. V.0 PRESENCE app evaluation

The next version of the PRESENCE applications is called the V.0 PRESENCE app, and is an extension of the First Playable apps with the three technical pillars integrated (for more information about the applications, see deliverable D5.2). In this study, 18 participants from the Vrije Universiteit Brussel participated in the UX survey. In this section, the full results will be presented.

Participant Demographic

18 participants (9 female, 9 male) with an average age of 32.44 (SD=6.41), all from Belgium (17 from Brussels, 1 from Antwerp) participated in this study. Participants were asked to indicate previous experience with XR (VR and AR) on an 11-point Likert scale, which resulted in an average score of 5.11 (SD=2.87) meaning that a majority of participants did not have extensive experience with XR. Participants were also asked about which PRESENCE application they used. As this was a multiple-choice question, participants could select multiple items. The results show that 6 participants used the Intelligent Virtual Human application, 10 participants used the Digital Touch application, 4 participants used the HoloConferencing application, 2 participants used the Professional Collaboration UC application, 3 participants used the Manufacturing Training UC application, 12 participants used the Health UC application, and no one used the Cultural Heritage UC application.

Quantitative results

SUS

The average SUS score of all PRESENCE applications used was 56.67 (SD=22.9). This indicates an OK usability of the application, which also shows that the application was marginally acceptable to users.

AttrakDiff

The results (see Figure 8) show neutral to positive evaluations for all four subscales of AttrackDiff: PQ (M= 0.21, SD=1.3), HQ-I (M= 0.15, SD=1.29), HQ-S (M= 0.53, SD=1.33), and ATT (M= 0.53, SD= 1.53). All values are slightly lower than in the previous evaluation of the First Playable app.

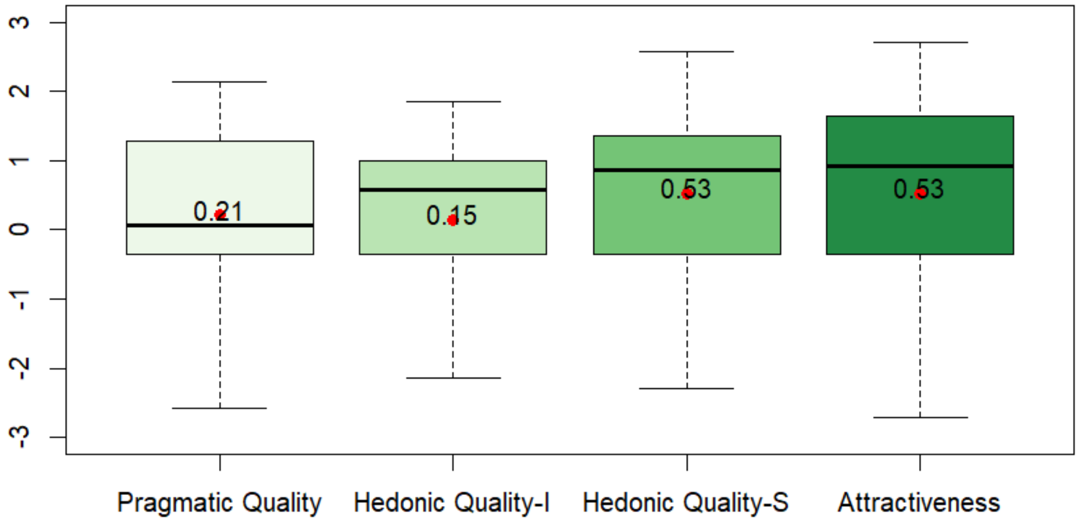


Figure 8: The results of the AttrakDiff questionnaire

IPQ

The results (see Figure 9) for the subscales of IPQ as well as the total sense of presence were as following:

- General Sense of Being There (M=4.22, SD=1.66)
- Spatial Presence (M=4.19, SD=0.85)
- Involvement (M=3.46, SD=1.1)
- Experienced Realism (M=1.67, SD=0.81)
- Total sense of presence (M=3.26, SD=0.8)

The results are comparable with the previous evaluation of the First Playable app without the technical pillars integrated.

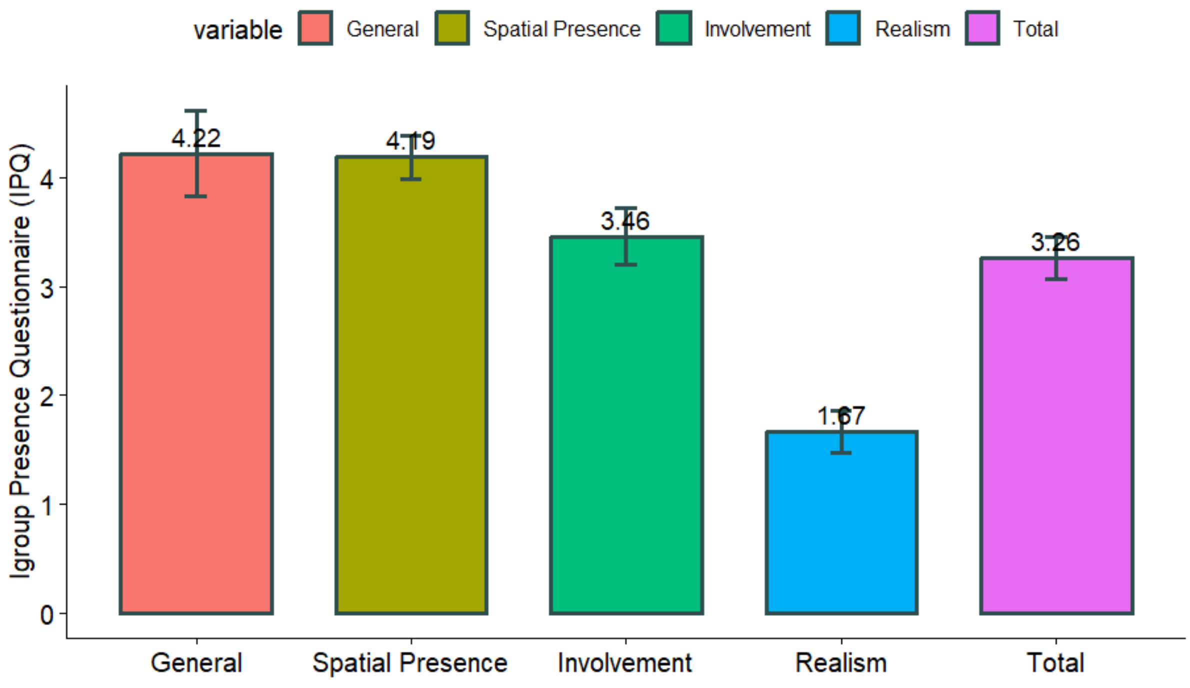


Figure 9: The results of the IPQ

Social Presence Questionnaire

For this round of evaluation, the Social Presence Questionnaire was updated to repeat itself four times to measure users' perception of:

- Basic avatar (a representation of a real user, but with no human-like features)
- Advanced avatar (a representation of a real user with human-like features)
- Holoported person (3D reconstruction of a real human)
- Intelligent virtual agent (an AI-powered digital being that can act and think on its own)

The results (see Figure 10) show neutral to negative evaluation for all types of virtual humans:

- Advanced avatar (M=0.42, SD=1.52)
- Basic avatar (M=-0.58, SD=0.88)
- Holoported person (M=1.55, SD=0.66)
- IVA (M=-1.68, SD=0.98)

As can be seen in Figure 10, the holoported person caused the highest and the IVA the lowest social presence score among participants.

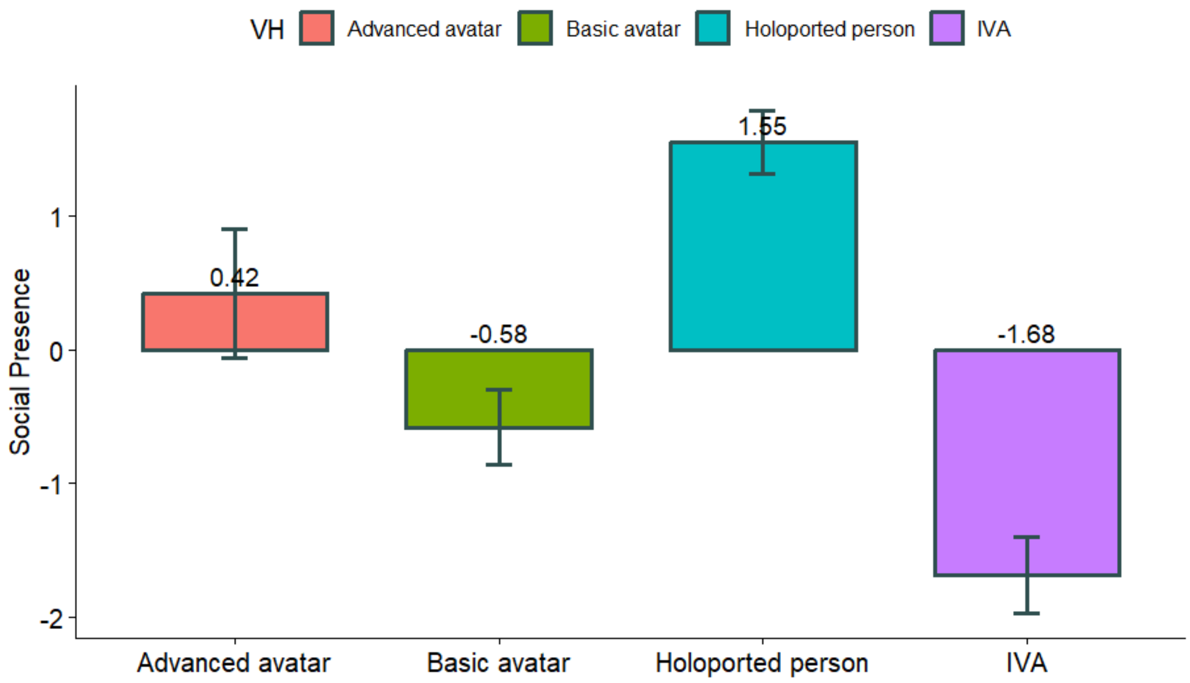


Figure 10: The results of social presence questionnaire

<u>TAM2</u>

The results (Figure 11) show neutral to moderate evaluations:

- Intention to Use (M=3.62, SD=2.14)
- Perceived Usefulness (M=3.27, SD=1.99)
- Perceived Ease of Use (M=4.36, SD=2.12)

All scales have reduced scores compared to the first playable app evaluation.

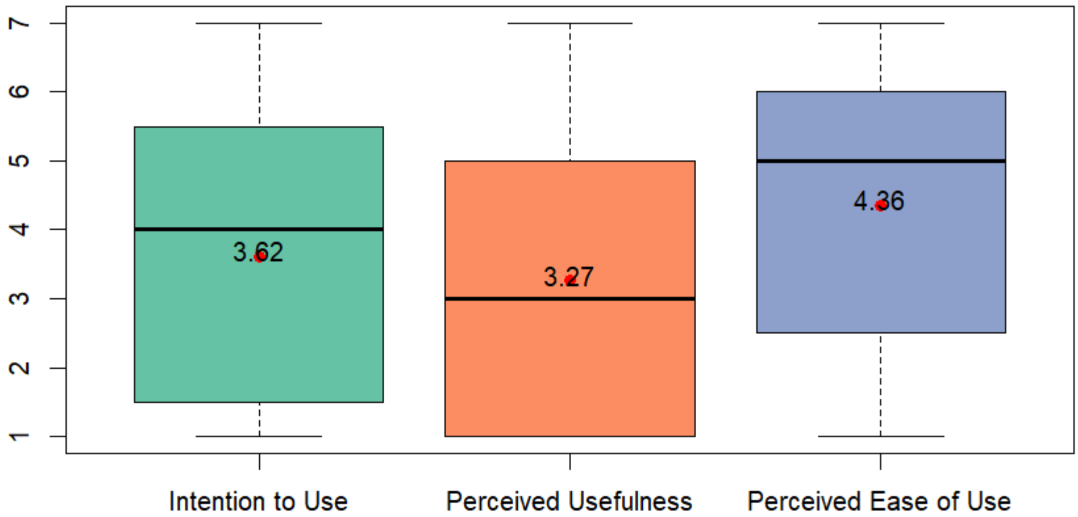


Figure 11: The results of the TAM2 questionnaire

3.3.5. Trustworthiness & Robustness of AI

The activities related to trustworthiness and robustness of AI are coordinated by T1.3. D1.1 has laid out the basic methodology (Section 3.2.3), which is based on the HLEG's Assessment List for Trustworthy AI (ALTAI[3]). It also discusses the state of the art of approaches to analysis of bias of AI systems.

When preparing D1.1, a registry[4] of AI components have been established and initially populated in M5, to be maintained as a living document. In this initial phase, the AI components were still under development, and developers provided information on the AI methods being used, the data sets used for training, as well as a self-assessment of the risk level according to the AI Act [Ref. 5]. This analysis has been updated in three aspects:

- **Review of the list of AI components:** The available deliverables of WP2, WP3, WP4 and WP5 have been analysed. This analysis has confirmed that the list of AI components collected in M5 still covers all relevant components.
- **Update of assessment with regard to the AI Act:** In addition to the risk self-assessment reported in the initial assessment, a more detailed assessment of applicable aspects of the AI Act has been performed, as detailed in Section 3.5.1.
- **Application of ALTAI:** The methodology described in D1.1 has been applied to the AI components in the list. As expected, and also discussed in D3.1, there are some aspects of ALTAI that do not apply to isolated components, and the assessment given by the ALTAI tool does not appropriately take into account aspects that are not applicable [Ref. 6].

As bias analysis will require assessing a representative set of model outputs, this work will be done once the models are deployed in the UCs, so that sufficient samples can be generated.

Another future assessment task is to check AI components for compliance with relevant standards developed by CEN/CENELEC JTC21 for implementing the AI Act. Section 3.5.2 discusses the available standards.

As the demonstrators are shaping, workshops for analysing and discussing the ethics issues related to the UCs and the use of AI in them are organised during summer 2025. The findings of the workshops will also inform the AI trustworthiness assessment in the context of the UCs.

Assessment of applicable aspects of the AI Act

1. For the AI components it is important to assess which aspects of the AI Act [Ref. 5] are applicable, in particular, concerning the risk assessment and the resulting obligations, for example, in terms of transparency requirements.

The first question is whether an AI component actually has properties that make it subject to the definition of an AI System provided in Art. 3. For example, a component relying on traditional

[3] https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=68342

[4] Notice to the attention of the EU Officers and external reviewers: most of the below URL links direct to the project Repository and thus with access limited to the project consortium members. The documentation is available under demand, contact info@presence-xr.eu.

statistical methods may be out of scope of the AI Act. To support such assessments, the European Commission (EC) has issued a guideline document in Feb. 2025 [Ref. 7]. However, working with this lengthy document is still challenging for AI system developers without legal background. As response to the consultation for the guideline document, the ELI has proposed a three-factor methodology, see also Figure 12 [Ref. 8]. The basic idea is to break down the AI System definition of Art. 3 into three aspects: the first focusing on whether the method is data-driven or uses expert knowledge from the domain, the second on whether the system adapts to new data during operation, and the third on the degree of determinacy of the output. Each factor is scored on a scale from 0 (does not apply), over + (applies to some degree) to ++ (fully applies), and a result of a total of 3 or more + means that the definition is considered applicable. We have adopted this approach and provide the results in the AI component registry.

Factor I:	Use of data or domain-specific expert knowledge in development
... infers, from the input it receives, how to generate outputs [input is training data]	
... for ... implicit objectives [model development objectives]	
++	*data-driven programming (ML), expert-systems, ontologies, ...*
+	*heuristic rules from experts*
0	*no domain-specific data analysis* *no expert knowledge*

Factor II:	Creation of new know-how during operation
... infers, from the input it receives, how to generate outputs [input is live data]	
... for explicit ... objectives [system execution objectives]	
... may exhibit adaptiveness after deployment	
++	*goal oriented optimization, online reinforcement learning, inverse model calculations, deductive inference, search in complex data spaces*
+	*NP-complete algorithms, navigation, scheduling*
0	*pure forward calculations, deterministic or stochastic results, predefined calculation steps*

Factor III:	Formal indeterminacy of output
... designed to operate with varying levels of autonomy	
... outputs such as predictions, content, recommendations, or decisions	
... can influence physical or virtual environments	
++	*no formal criteria to define correctness of results, humans instead of the AI would exercise discretion, subjectivity in generation of outputs*
+	*variability of outputs but no subjective discretion; fixed distribution of results*
0	*clearly formally defined outcomes, variability of results are perceived as substantially identical by humans, general database systems, word processing programmes*

Figure 12: Three-factor approach for assessing whether the AI System definition of Art. 3 of the AI Act is applicable (from [Ref. 8])

The second question is whether the risk assessment based on the component alone can be considered the final assessment, or whether the UC dictates another risk assessment or transparency requirements. For this purpose, the UC description in D5.1 have been analysed to assess whether:

- The application in the UC is subject to Union harmonisation legislation according to Annex I, and thus to be considered high-risk application,
- The UC is a high-risk system according to Annex III, or
- The use of the AI component implies transparency obligations according to Art. 50.

The results of this analysis have also been added to the registry. It must be noted that we assumed that each AI component is potentially used in every UC, which may finally not be the case.

European standards implementing the AI Act

CEN/CENELEC JTC21 has a standardisation mandate from the EC to develop standards supporting the implementation of the AI Act. Many of the standards are still under development. Some applicable international standards developed by ISO/IEC JTC1 SC42 have been adopted, however, where there is a need to adjust the standards to European requirements, modified or new standards must be developed. The adopted standards include terminology, AI framework and model life cycle, and analysis of bias and robustness of AI systems. A few own technical reports and specifications, for example on data governance and quality, have already been published.

Results

First, the AI component registry has been updated with regard to the applicable aspects of the AI Act. The main findings can be summarised as follows:

- All collected components fall clearly under the definition of an AI System according to Art. 3. While no component performs adaptation during runtime, all components are strongly data driven, and have at least some degree of indeterminacy of the output.
- As the Large Language Models (LLM) for interaction are directly user facing, users need to be clearly informed that they are interacting with an AI System according to Art. 50.
- The generated humanoid models need to be identified as AI generated according to Art. 50.
- Currently the solution for the health UC does not fall under the scope of the regulation for medical devices. If this changes in future, this might imply a classification of some of the AI components used in the solution as high-risk.
- The manufacturing UC involves a training scenario, which potentially implies a high-risk system according to Annex III. However, according to the current description of the UC, no AI-based assessment of outcomes or automated steering of contents is planned, and thus the UC is currently considered outside the scope of Annex III.

Second, selected components have been assessed, following the ALTAI method. We provide a summary of findings in the following paragraphs.

<u>Human action recognition/prediction</u>

Human agency and oversight is only applicable in the training and development process for a component that provides real-time information on actions. Any option for human intervention would be disturbing to immersion. This applies similarly to many aspects of *Transparency*, as explainability and feedback is not feasible during regular operations. What is relevant in terms of transparency is to clearly communicate that the users are interacting with an AI-powered component, including how the Intelligent Virtual Human perceives and reacts to actions. However, this has to be done on the level of the demonstrator system and cannot be done for the interaction component.

Many of the aspects of ALTAI under *Diversity, non-discrimination and fairness* are less critical as the component's decision only impacts the quality of interaction by possibly reduced performance in action recognition, however, this does not impact the quality of responses provided to the user but may reduce the quality of experience.

While *Technical robustness and safety* aspects related to possible damages based on the AI's performance do not apply, the issue of ensuring accuracy in the target environment (which may have different actions or appearance of actions than those used during training) does apply. While no direct feedback on correct decisions is available, it might be possible to gather some implicit information from repeated interaction patterns due to failure of the component to identify actions. This is related to aspects of *Accountability*, such as allowing users to flag unexpected or low performance. One approach to monitor accuracy could be logging and auditing. However, this requires capturing and storing parts of the visual interaction that would otherwise only be transient, thus potentially creating privacy issues.

Concerning *Privacy and Data Governance*, some desirable measures concerning the input data cannot be addressed at this point, as pretrained models have been used. Thus, the project partners do not have control over governance of the training data. This might change in future versions of the component, that might be trained or fine-tuned on own data.

The aspects of *Societal and environmental well-being* are not applicable in this case.

3D humanoid model generation pipeline

Like for other PRESENCE components, *Human agency and oversight* applies to the offline processes, i.e. training of models and the creation of avatars. One aspect to consider during operation of the system is the risk of users developing attachment to Intelligent Virtual Humans, i.e. non-existing persons. In terms of *Transparency*, explainability and feedback is not feasible during regular operations. What is relevant in terms of transparency is to clearly communicate that the users are interacting with an AI-powered virtual human (to be done on the level of the demonstrator system).

While *Technical robustness and safety* aspects related to possible damages based on the AI's performance do not apply, accuracy might only impact the credibility and realism of the avatar. *Accountability* could be strengthened with a mechanism for users to flag issues they perceive with the avatars, or report situations in which they feel uneasy in the interaction with the avatar.

The aspects of *Privacy and Data Governance* mainly concern the management of training data for Intelligent Virtual Humans. For Smart Avatars, there are clear consent procedures addressing any privacy issues. For Intelligent Virtual Humans, the management of training data is also related to the *Diversity, non-discrimination and fairness* aspects, ensuring that the generated avatars are unbiased and not reproducing stereotypes.

The aspects of *Societal and environmental well-being* require the analysis of the implications of collaborating with an avatar possibly representing a non-existing person, both in work and leisure UCs. This analysis cannot be done generically for the avatar generation technology but is UC specific.

Movement controller

Like for other PRESENCE components, *Human agency and oversight* applies to the offline processes, i.e. training of movement controllers. There is an option to stop the movement controller by pushing the character (not currently included in the demo). However, this needs to be implemented in the demonstrator application, not in this component). In terms of *Transparency*, explainability and feedback is not feasible during regular operations. However, depending on the UC, it could be explored whether there are options to allow users to provide feedback or guidance.

While *Technical robustness and safety* aspects related to possible damages based on the AI's performance do not apply, accuracy is related to the quality of movements. In case the virtual character is deployed to different environments, adding monitoring of motions could address ensuring that the initial level of accuracy is kept. This could be supported by *Accountability* measures for logging data. Logging would require storing user interactions, which raises potential privacy issues.

The aspects of *Privacy and Data Governance* mainly concern the management of training scenarios. There is documented consent concerning the capture of the movement data used for training. There are no relevant aspects of *Societal and environmental well-being* for this component.

Speech and facial interaction

Privacy and Data Governance are beyond control of a consortium member, as this component relies on third party cloud services. This also applies to some aspects of *Transparency*, in particular the training data. As for other components, explainability and feedback is not feasible during regular operations. What is relevant in terms of transparency is to clearly communicate that the users are interacting with an AI-powered avatar. However, this has to be done on the level of the demonstrator system and cannot be done for the interaction component.

Human agency and oversight cannot be applied to the training stage and is not feasible during the experience. Thus, *Accountability* becomes crucial, (i) in terms of logging interactions to monitor for bias or failures of the interaction, and (ii) by providing users the option to flag issues they perceive. Such monitoring is also important to address *Diversity, non-discrimination and fairness* aspects. Again, the training data and process are beyond control, thus monitoring for any possible discrimination in the interaction with the LLM, or issues of the speech interaction for some user groups need to be assessed.

Technical robustness and safety can be addressed here by monitoring the accuracy and performance of the system, in particular when deployed in contexts that differ from those used during development.

For addressing *Societal and environmental well-being* it needs to be ensured that users in work contexts are appropriately trained.

3.4. Presence Evaluation

This chapter outlines the work carried out to evaluate presence and co-presence across different VR scenarios. The aim is to assess how users experience immersion and social interaction when using different XR technologies. Several experimental setups, some already completed and others ongoing, feed into this broader goal.

3.4.1. Museum experiment

Unlike prior studies within PRESENCE that focus on specific applications or project technologies, this experiment was designed as a general-use scenario to investigate how different XR technologies influence user experience, particularly in terms of presence and co-presence. Serving as a general-use scenario, or as an abstraction of all UCs, results can be applied across the UCs without the need for separate studies.

The experiment takes place in a virtual museum (Figure 13, Figure 14), where three remotely located participants collaborate in real time to arrange artworks. As objects cannot be moved individually, two participants must act together to manipulate them, adding a layer of coordination. In addition, participants must ensure compliance with virtual safety constraints such as keeping exits, fire alarms, and extinguishers unobstructed. Some objects demand fine manipulation, which serves to further challenge participants' coordination.

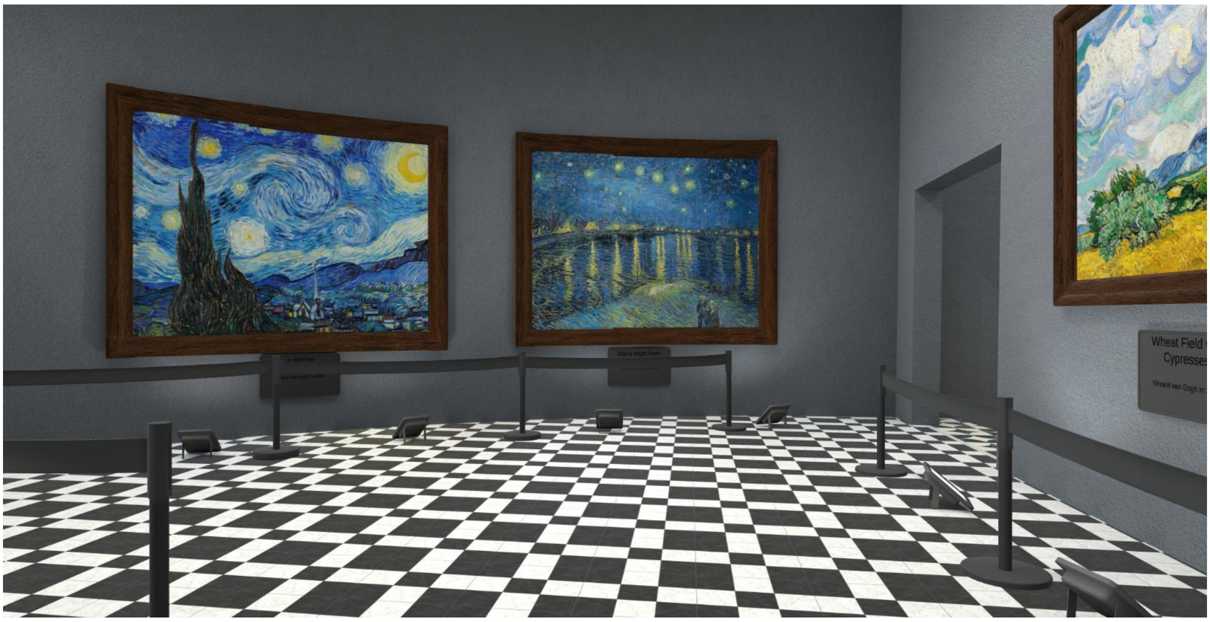


Figure 13: One room in the museum environment with scans of paintings by Vincent van Gogh

The inclusion of exactly three participants allows for observation of emergent group dynamics, such as when one person takes on a leadership or supervisory role. This setting provides insight into how social structures develop spontaneously in shared XR environments.

In a second phase, three additional individuals (either other remote participants or IVAs) enter the environment and the original trio gives them a guided tour. This transition introduces a new mode of interaction that reflects elements from cultural heritage scenarios.

Although simplified, the museum experiment draws inspiration from all four major PRESENCE UCs: Professional Collaboration, Manufacturing Training, Health, and Cultural Heritage. The setup incorporates core aspects from each, including the need for synchronous action across distant locations, safety-critical interactions, embodiment of remote participants, and meaningful content delivery.

Technologies integrated into this experiment include Didimo avatars, Intelligent Virtual Humans, and haptic devices (such as the haptic gloves by SenseGlove) that simulate tactile responses. For example, the experiment explores using normal and height maps to simulate touch textures across all virtual surfaces or providing haptic feedback during handshakes. These interactions are enriched by the presence of virtual humans that serve as collaborative agents or passive observers.

The environment runs on Meta Quest 3 HMDs, and multiuser support has been integrated. The haptic gloves by SenseGlove have been integrated, including tactile feedback of virtual surfaces. However, some interactive elements (such as controller buttons, joysticks, and the integration of two-player mechanics and IVAs) are still under development.

Recruitment has been delayed due to administrative issues at the University of Barcelona, shifting the original timeline of the experiment.

Figure 14: Room in the museum environment containing several scans of bust by famous scientists, including Charles Darwin, Marie Curie and Albert Einstein

Presence and Co-Presence are in this study assessed through questionnaires (Place Illusion and Plausibility scales), behavioral logging (task efficiency, interaction fluency, and error rates), and Adaptive Multi-Modal Matching (A3M) that uses Thompson sampling to propose adjustments to factors such as avatar appearance or control schemes. Participants experience these alternatives briefly and can choose to accept or reject them. Their decisions are logged, and are later analyzed using Markov chain models to understand decision patterns. This analysis captures transition probabilities between configurations and provides insight into user preferences and the likelihood of accepting specific changes based on current settings. Through this method, the experiment models how users navigate trade-offs between competing aspects of the virtual experience.

Additionally, sentiment analysis is applied to participant comments or spoken feedback to extract emotionally nuanced data that might not surface through structured surveys.

3.4.2. Eye-tracking, brain synchrony and self-evaluations to study co-presence in VR

This section presents a set of experiments designed to explore co-presence using eye-tracking, Electroencephalogram (EEG), and self-report methods. The aim of these experiments is to assess how users perceive others, align attention, and collaborate in social VEs.

Gaze-guided learning of foreign words in social VR interactions

A study with **38 participants** investigated whether adults use gaze cues from virtual agents to learn new words in a second language. Conducted at the **University of Barcelona (January-May 2025),** the study used eye-tracking and presence and sentiment self-evaluations, which helped provide proof of concept for the later behavioral version of the ‘The Mind study’.

In this study, participants interacted with virtual teachers whose gaze behavior was either helpful, misleading, or random. Learning outcomes were seen as higher when participants followed the informative gaze cues, which supports that gaze-following aid language learning in children. First, participants listened to a phonetic word input (outside of VR), then they entered the VE for a Gaze-cue task where they learned with feedback from a virtual agent under three conditions (Good, Random, or Bad teacher). Participants then completed an Overt naming task and an Initial word recognition task within each block. At the end of learning, they took a Final word recognition task, which assessed learning outcomes. Once again outside of VR, they completed a presence rating and self-report (see also Figure 15).

In Figure 16, the different learning phases can be consulted. Box A presents the three teachers, box B illustrates the Gaze-cue task where the participant sees two objects, the agent names one of them and either gazes at the correct (Good teacher), incorrect (Bad teacher) or at the random (Random teacher) object. Here, the gaze following is also included, to show that the participant is looking at and following the gaze of the agent towards the correct object (the word ‘rabbit’). When the participant points to one of the objects, the agent gives them feedback as to whether the answer is correct or not. In box C, the Overt naming task is illustrated. Here, the participant sees one of the objects they have just learned and is asked to name it if possible. Following this they point to the object and the agent says the correct label. Box D illustrates the Word-recognition task, where the participant sees four objects and the agent names one of them (without gazing at any of them). The participant then points to one of the objects and receives feedback for their performance.

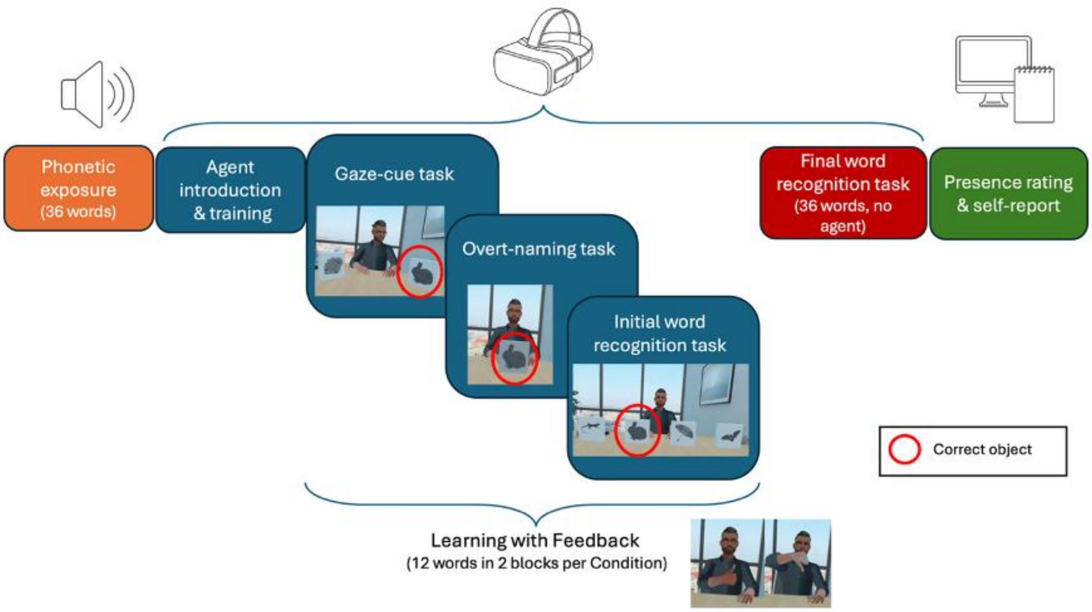


Figure 15: Illustration of the different phases of the study

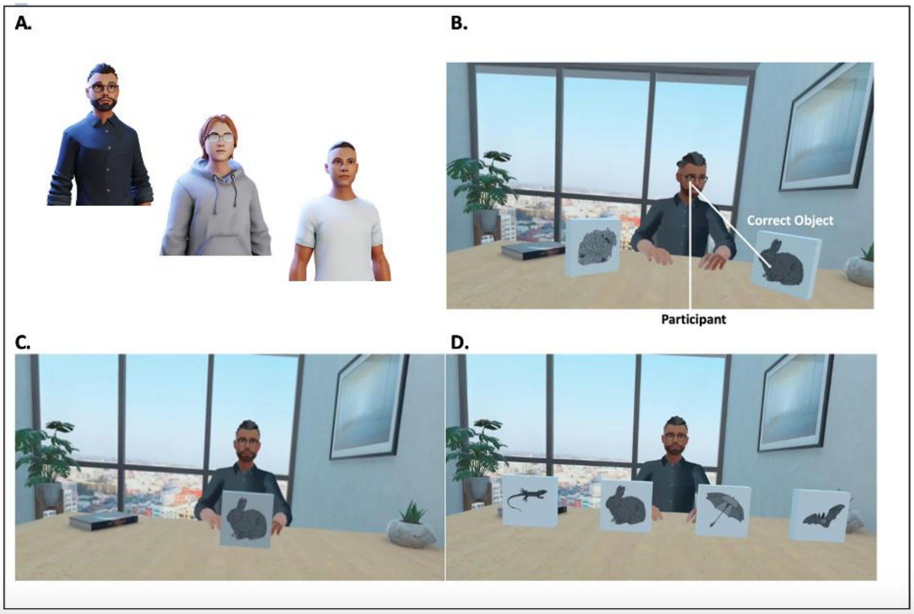


Figure 16: Learning phases

Results

Behavioral performance

Performance was based on the accuracy recorded during the *Gaze-cue task,* and both *Word recognition tasks.*

Eye-tracking

Eye-tracking captured gaze behavior as an indicator of attention during the *Gaze-cue task*, specifically while the agents' produced words. Fixations that occurred during this phase were analyzed, targeting the following areas of interest: the two objects, the agent's right eye, left eye, and mouth. Fixations were only considered valid if they lasted at least 100 milliseconds.

Gaze-following was defined as the participant first fixating on the agent's eyes (right or left) for at least 100 milliseconds, then shifting their gaze within 100 milliseconds to the object the agent subsequently looked at (Figure 16). Since brief glances over other objects can occur while moving from one fixation point to another, and 100 milliseconds is considered the minimum duration required for conscious attention to an object, this sequence was categorized as a gaze follow.

Presence questionnaire

Presence was measured via the Spanish version of the Slater-Usoh-Steed (SUS) [Ref. 9] Presence Questionnaire. This questionnaire was designed to measure the feeling of being in the virtual world rather than just observing it and consisted of 5 key questions scored on a 7-point Likert scale. 1 indicated a very low sense of presence, and 7 a very high sense of presence, apart from Q4 which was negatively phrased and hence reverse-scored. The questions can be seen in Figure 25.

Free-form self-report

After the VR session, participants wrote a free form description of how they felt about the virtual environment, the virtual agents and overall experiment (250 words approximately). These texts were analyzed qualitatively and, as all responses were written in Spanish, a multilingual BERT sentiment analysis model was also used to classify emotional valence (Very Negative, Negative, Neutral, Positive, Very Positive) [Ref. 10; Ref. 11; Ref. 12].

Figure 17 below shows color coding to distinguish between conditions, with green for Good teacher, orange for Random teacher and light red for Bad teacher. Flat violin plots represent the distribution of individual participant scores for each condition, with width indicating density, boxplots show medians and interquartile ranges, and jittered points display individual participant scores.

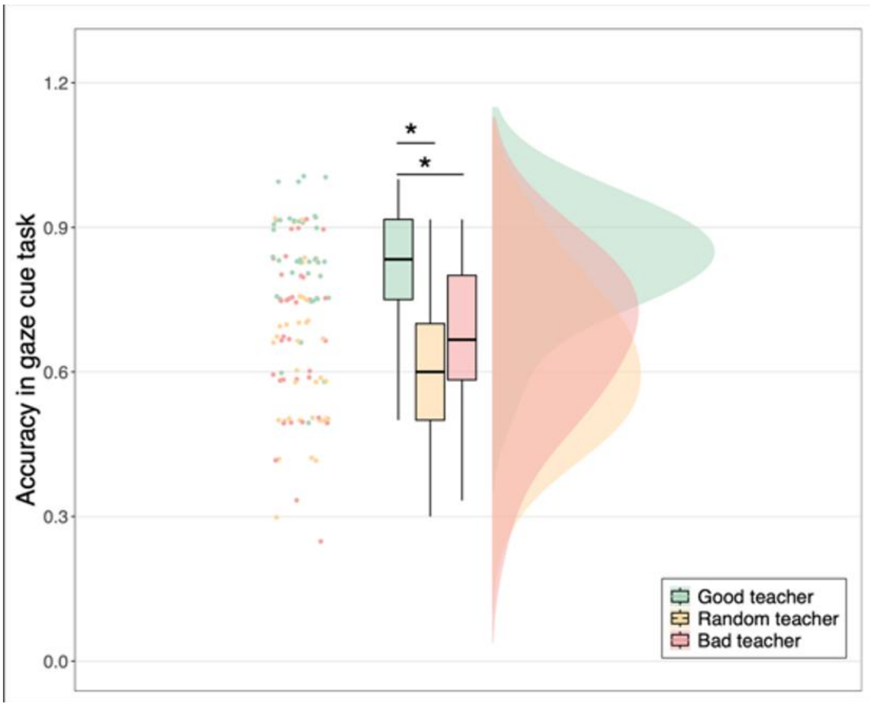


Figure 17: Participant accuracy during Gaze-cue task as a function of learning condition

As shown in Figure 18, for each learning condition (Good teacher vs. Bad teacher), behavioral accuracy is split by gaze-following status (Gaze-following vs. No gaze-following). Color coding distinguishes between conditions, with lighter blue for No gaze-following and darker blue for Gaze-following. The asterisk marks a statistically significant difference between gaze-following and no gaze-following within the Good teacher condition (p < .01).

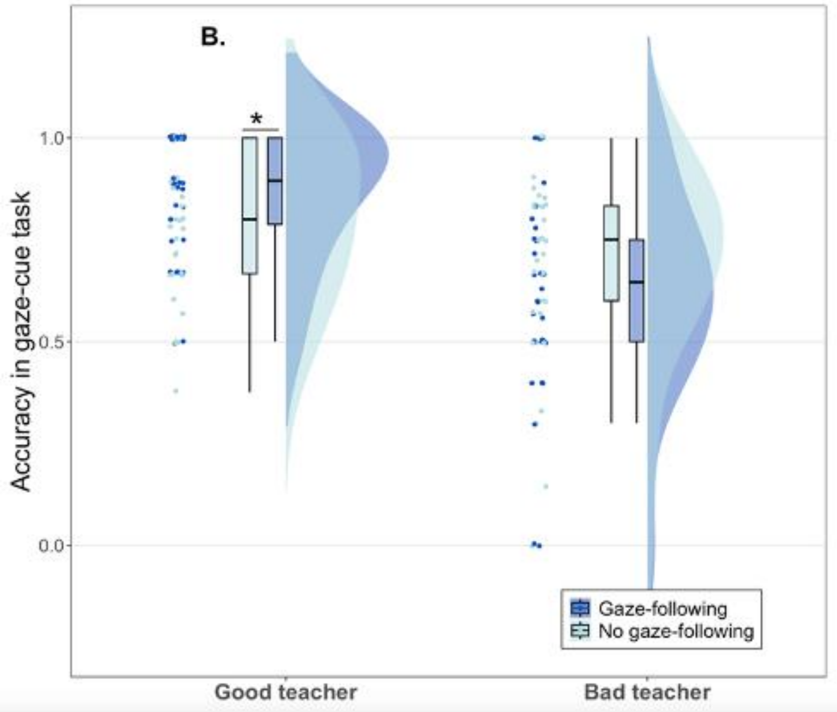


Figure 18: Final word recognition accuracy as a function of gaze-following behavior and learning condition

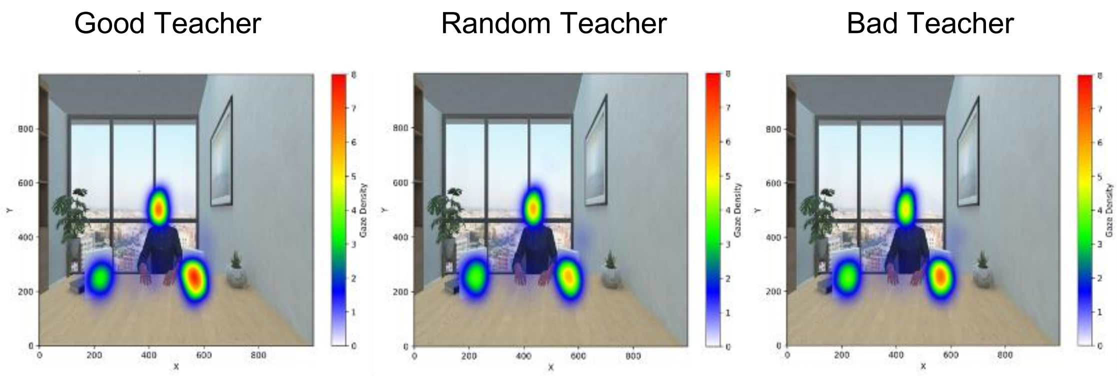


Figure 19: Heatmaps of transformed points density plots

Figure 19 above shows the mean over all participants of the density of gaze to the agent's face, and the correct (right side here for the purposes of visualization) and incorrect (left side) objects in the three different learning conditions. Gaze density towards both the teacher's face and the correct object was the strongest in the Good Teacher condition.

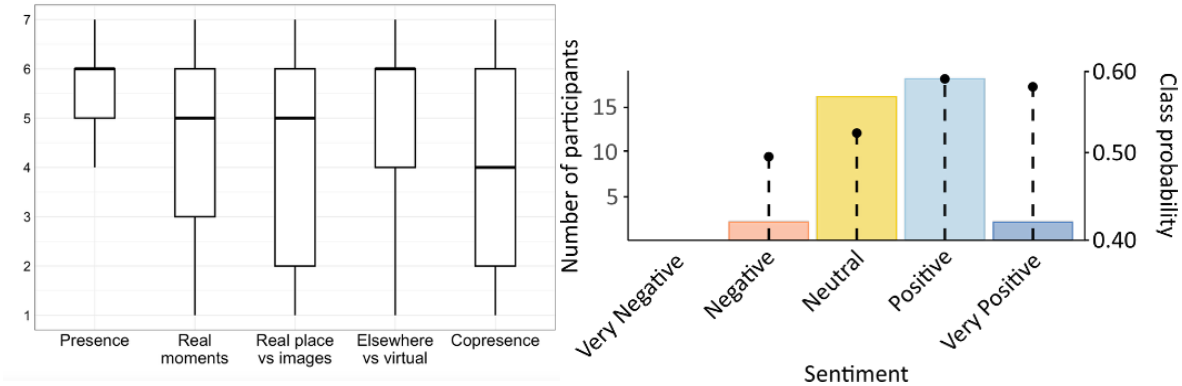


Figure 20: Presence evaluation and Sentiment analysis

In Figure 20, the left-hand side (Box plots with overlaid jittered points) shows the results of the questionnaire used to assess the feeling of presence, evaluated on a 7-point Likert scale. For all items – "Presence", "Real moments", "Real place vs images", "Elsewhere vs virtual" and “Copresence” – a higher score indicates a higher feeling of presence, (for the sake of visualization we inverted "Virtual vs elsewhere" scores to “Elsewhere vs virtual”). The box plots display medians and interquartile ranges. On the right-hand side, sentiment analysis of participants’ written descriptions of their experience during the experiment is shown. Each text was assigned a sentiment score reflecting its emotional valence. The histogram quantifies the emotional valence of each text (Very negative, Negative, Neutral, Positive, Very positive). The right axis indicates the class probability for sentiment analysis, showing that all classes have high probability values (black dots).

This study provided valuable insights into conducting eye-tracking analyses, particularly in the use of density plots and gaze-following measures. Gaze duration analyses are especially informative for the behavioral and eye-tracking versions of *The Mind*. Additionally, the study offered further validation of our presence questionnaire and supported the utility of sentiment analysis in capturing participants' subjective experiences.

This study contributes to KPI 1.3 by validating a novel behavioral and eye-tracking methodology to evaluate social presence and co-presence in immersive language learning contexts. Through analysis of gaze-following, gaze density, and time spent on social agents’ faces, it offers fine-grained behavioral and attentional metrics relevant to both plausibility and **co-presence**. Additionally, participants' responses on presence questionnaires and sentiment analyses inform our understanding of **place illusion** and **subjective engagement,** reinforcing the methodological basis for assessing presence across multiple dimensions.

The Mind game experiment

The Mind game experiments form a central part of the work on studying cooperation and social presence in VR. In these studies, the same methodology is used as described for the Gaze-guided learning experiment, but here the cooperative game called The Mind is used (see Figure 21 below). In the game, groups of three participants are immersed in a virtual environment to cooperate. The players receive cards with numbers and must play them in ascending order without speaking or using gestures. To succeed, subtle coordination, attention, and shared timing are essential.

Figure 21: The environment for The Mind game

In the game, participants are seated around a virtual table, with a central display showing played cards and individual private displays for each player (see Figure 21). It unfolds in three phases (as seen in Figure 22 below):

1. In the first phase (blue), participants see a number in the central display and are invited to play a card if they believe they have the lowest number.
2. If they play, the game moves to the second phase (yellow), a short wait (2 secs) during which they must wait to see if the card played was correct.
3. Finally, in the last phase, participants learn the outcome – green for correct and red for incorrect – and either continue playing the next card (or move on to the next level if there are no cards left) or repeat the level (if they got an incorrect answer).

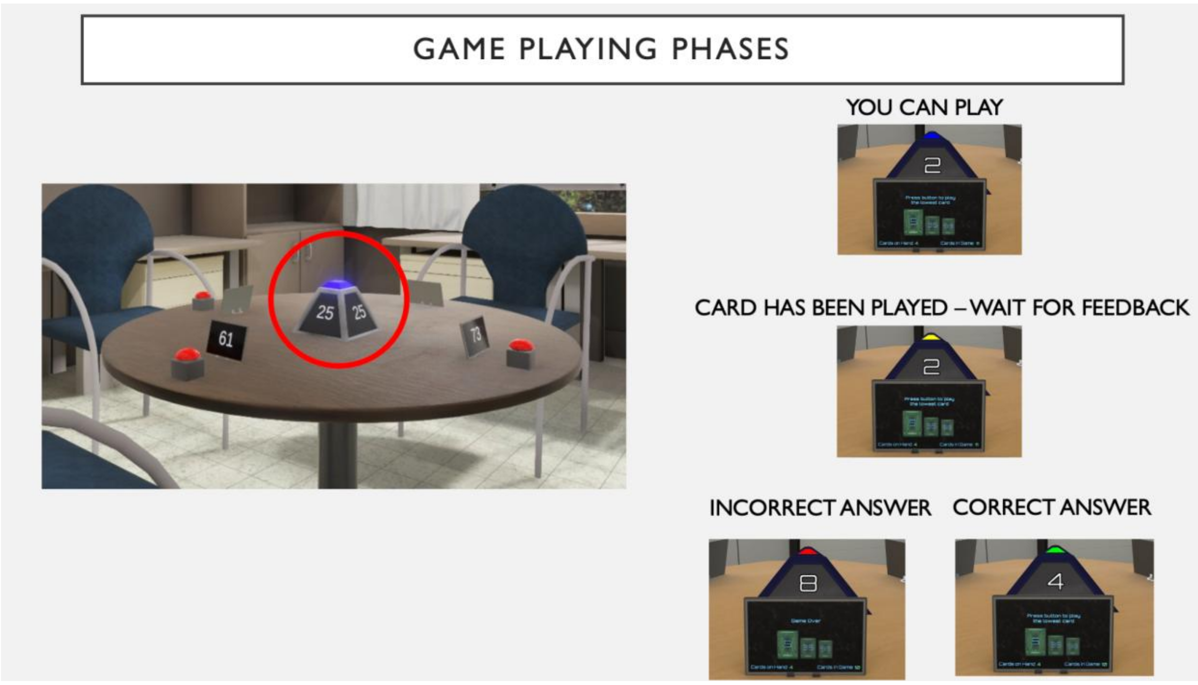


Figure 22: The different phases of the Mind game

This task forms the backbone of a **multi-method paradigm for evaluating co-presence** in VR. It provides an ecologically valid cooperative game structure within which different technologies (behavioral measures, eye-tracking, EEG) can be applied to study **social engagement**. By capturing gaze patterns and self-reported presence during each game phase, key elements of **place illusion, plausibility, and co-presence** can be evaluated. This game-based format thus serves as a reusable framework to compare user experiences across technologies and experimental variants.

EEG version of The Mind experiment

One major strand of this work focuses on brain-to-brain synchrony as an objective measure of co-presence. Using EEG hyperscanning, neural activity from all three players can be recorded simultaneously as they're playing. This allows for the computing of intersubject correlation (ISC) which is the degree to which players' brain signals align over time. Prior research shows that ISC can index group-level engagement, such as in classroom settings, where brain-to-brain synchrony has been linked to attention and learning outcomes. By analyzing EEG-ISC, the aim is to establish it as a neurophysiological marker of co-presence in immersive environments.

This study directly addresses KPI 1.3 by introducing **neural synchrony** (EEG-based ISC) **as a novel, objective marker of co-presence**. In addition to subjective measures and physiological responses, this method captures shared attention, social presence, and plausibility at the neural level during multiplayer VR interactions. Event-related potentials (ERPs) is also used to measure result expectation and processing during the different phases of the game (see Figure 23). The pre-result (yellow) phase is used to study stimulus-preceding negativity (SPN) ERP as a marker of expectation, while the result phase (red or green) is used to study error-related negativity (ERN), often called the "oops" ERP, as a marker of self or group evaluation. During the behavioral and eye-tracking version of the experiment, gaze is measured as a marker of co-presence during each individual phase in an exploratory manner.

Presence and co-presence are assessed using a multi-method approach, where neural synchrony is measured through sliding-window ISC analysis and physiological responses (such as heart rate and respiration) are recorded. Participants also complete self-report evaluations of presence and social experience, which supplement the sentiment analysis.

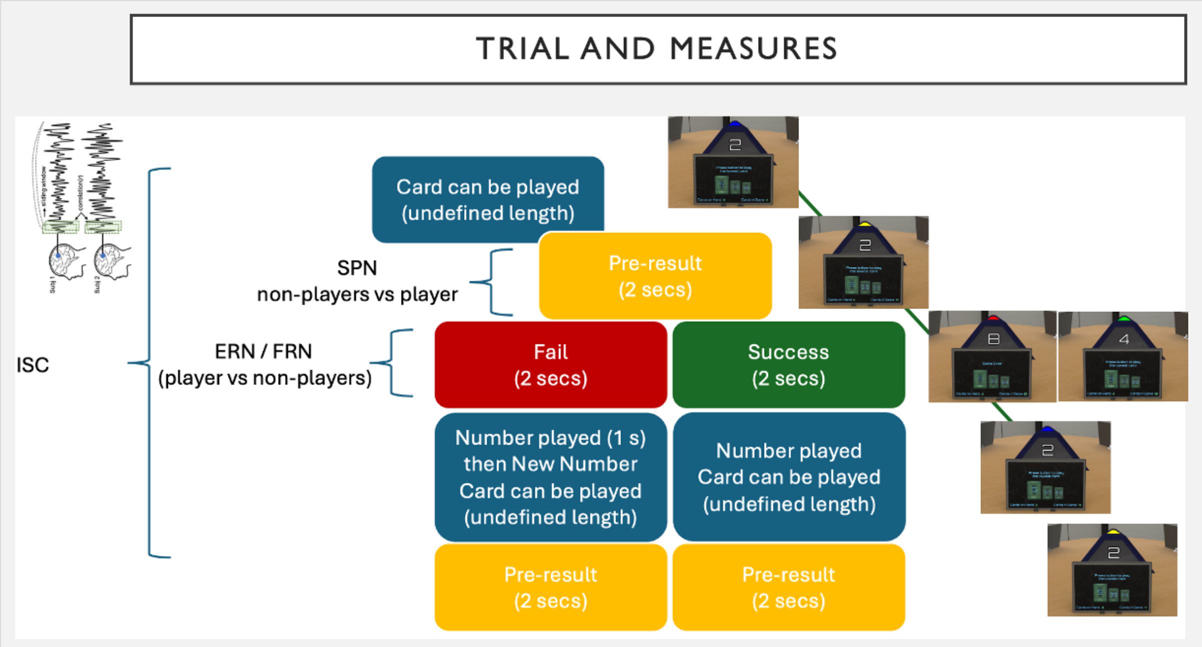


Figure 23: How the different phases of each trial will be used in the EEG version of the experiment

We formulated three main hypotheses regarding EEG measures of co-presence and collaborative gameplay. First, we hypothesized that participants would experience a sense of co-presence while playing collaboratively, which would be reflected in increased brain-to-brain alignment during gameplay compared to the resting state. Second, we predicted that as the game progressed, participants would feel increasingly connected as a group. This would manifest as greater interbrain synchrony during the second half of the game relative to the first, along with increased similarities between the neural responses of the player who is "responsible" for each play and the others during the pre-result and result phases (SPN and ERN/FRN). Third, we hypothesized that higher subjective presence and engagement would be associated with better task performance. Accordingly, we predicted positive correlations between performance and interbrain synchrony, as well as between performance and reductions in SPN and ERN/FRN differences between players and observers over time.

Running these kinds of experiments are technically demanding. Each participant wears a Meta Quest 3 headset, a 32-electrode Biosemi EEG system, a heart-rate monitor, a respiration belt, as well as the technical equipment needed to run the experience and synchronize data (through the Lab Streaming Layer (LSL)). The experiment will be conducted at the University of Barcelona (Campus Mundet). Recruitment is currently in progress, with a target sample of 30 student volunteers, recruited via the UB SONAR system and campus flyers. Each session lasts approximately 1.5 hours, including consent procedures, participant forms, written instructions, headset adaptation, training, resting-state recordings, two gameplay sessions, a break, and final questionnaires. So far, two pilot sessions involving three participants each (6 participants total, March 2025) have been completed and analysis is underway.

<u>Custom plugin for precise VR-EEG synchronization</u>

Accurate timing between what participants see in VR and what is recorded in EEG is crucial for meaningful analysis, but it's still a challenge as even small delays can distort ERP results. Prior studies [Ref. 13] have mitigated this with a proof-of-principle implementation using a different engine and VR runtime. That original solution, while effective as a demonstration, was never intended to be a plug-and-play tool.

Despite the visibility of this issue in the literature, little progress has been made in practical solutions. For our current PRESENCE study, proper timing alignment is crucial for meaningful analyses such as ERPs and time-frequency EEG decompositions. As a result, we have now developed a robust synchronization method tailored for the Meta Quest platform and Unity. This solution is considerably more sophisticated than our earlier work and is being refined into a user-friendly tool that other researchers can readily adopt once the project is complete.

Specifically, a custom OpenXR plugin was created to capture the exact predicted display time of each rendered frame. This enables precise timestamping of visual events, which are then synchronized with EEG recordings through Lab Streaming Layer (LSL).

The OpenXR standard provides a mechanism to address this issue through the function xrWaitFrame(). This function returns an XrFrameState structure that includes a field named predictedDisplayTime, which indicates the estimated system time at which the frame currently being prepared will be displayed on the headset. Access to this value enables frame-accurate synchronization between visual events and external signals, including EEG.

Since Unity, by default, does not expose the predictedDisplayTime to user scripts, a native C++ OpenXR plugin was developed. This plugin is compiled into a shared library (.so) for Android-based standalone VR devices such as the Meta Quest. The plugin works by intercepting Unity's internal call to xrWaitFrame() through a custom implementation of xrGetInstanceProcAddr(). When the function name "xrWaitFrame" is detected, the plugin replaces it with its own version of the function. This replacement calls the original xrWaitFrame(), captures the returned predictedDisplayTime, and stores it in a global variable accessible from Unity via a C-accessible interface.

To integrate this functionality into Unity, a custom OpenXRFeature subclass is implemented. Within this class, the method HookGetInstanceProcAddr() is overridden. This method receives a pointer to Unity’s original xrGetInstanceProcAddr, passes it to the native plugin for internal use, and returns the pointer to the plugin’s custom proxy function. This ensures that all OpenXR function resolutions, including xrWaitFrame(), go through the plugin’s logic, allowing it to intercept and record the predicted display time without modifying Unity's internal rendering loop.

From Unity, the current predicted display time can be accessed via a static method that internally calls the native function GetPredictedDisplayTime(). This time value can then be used in synchronization with EEG data collection, for example, by sending it as a timestamp through LSL alongside event markers, or by associating it with stimulus events in a trial timeline.

This approach provides sub-frame-level temporal alignment between VR-rendered stimuli and EEG data, enabling reliable neural response analysis that depends on precise timing. The system is especially valuable in studies involving perception, attention, timing, or sensorimotor integration in immersive environments.

Given the logistical demands and the novelty of the multiplayer VR setup, it was decided to first conduct a simpler behavioral version of the study to gain initial insights into participants’ behavior and strategies before launching the full EEG study. The simpler behavioral version of the study is described in the section below and provided valuable experience in how to explain the task most clearly and efficiently to participants, and informal feedback from participants regarding their experience during the game, including the strategies they used and their understanding of the gameplay dynamics. This preliminary work has proven crucial for refining the experimental protocol and ensuring the feasibility and quality of data collection in the more technically demanding EEG version.

This technical advancement not only addresses a longstanding challenge in immersive EEG research but also exemplifies PRESENCE's commitment to enabling high-fidelity, neurophysiologically rigorous experiments in immersive environments.

This technical innovation supports KPI 1.3 by enabling precise temporal synchronization between immersive VR stimuli and physiological/neural recordings, which is essential for valid analysis of **co-presence, place illusion, and embodiment.** By capturing the exact frame timing of visual events, the plugin ensures that ERP and time-frequency EEG analyses accurately reflect participants' perceptual and cognitive states in response to social and spatial cues. This tool thus strengthens the **reliability and interpretability of multimodal presence-related metrics.**

<u>Eye-tracking and behavioral version of The Mind experiment</u>

Before launching the full EEG study, a behavioral version of The Mind game with integrated eye-tracking was conducted. This version served three purposes:

1. Validate the VE's ability to create a strong sense of presence.
2. Gather feedback on gameplay experience and strategies.
3. Explore gaze patterns as indicators of co-presence and predictors of task success.

This simpler behavioral version of the study helped determine the optimal time windows for EEG analysis in the full study, and it lasted about one hour, including consent and information procedures, headset adaptation, task training, gameplay in VR, and post-experiment questionnaires. Participants were tested in groups of three, and the setup included one Meta Quest 3 and two Meta Quest Pro head-mounted displays. Eye-tracking capabilities were integrated in the Meta Quest Pro headsets. Each participant used a Bluetooth mouse to interact during gameplay, and Unity software recorded behavioral and gaze data via a dedicated desktop.

<u>Preliminary results</u>

Presence and co-presence were assessed through eye-tracking data, as well as self-report evaluations of presence, engagement, and enjoyment, which are further analyzed through sentiment scoring. The surveys used in this study are presented in the Adjuncts' Section 8.6 and 8.7. Three pilot sessions with three participants each have been completed, and 27 participants have completed the full study, which took place at the University of Barcelona between April and June 2025.

<u>Self-report evaluations of general sentiment</u>

Many participants reported a generally positive experience with the virtual environment, highlighting feelings of immersion, fun, and a strong desire to keep playing, even after the experiment ended.

The environment was often described as well-designed, visually appealing, and realistic, contributing to a sense of presence and engagement. The gameplay itself was frequently characterized as motivating and collaborative, with emotional terms such as *liked*, *fun*, and *comfortable* appearing consistently across responses.

However, several areas for improvement were identified. Some participants felt disconnected from others, often due to limited realism in avatar movements or a lack of expressive facial cues, which affected their ability to fully interpret others' actions. Additionally, technical glitches, such as delayed reactions or unintended inputs, occasionally disrupted the sense of immersion. Comments also pointed to discomfort with awkward gestures or limited non-verbal communication, which reduced the natural flow of interaction in the virtual space. Despite these issues, the overall sentiment remained largely positive, underscoring the potential of such environments for engaging collaborative experiences.

Self-evaluation of Presence

Ratings across all five dimensions were generally high, with median scores clustering around 5–6 on a 7-point scale. Participants reported strong overall presence and co-presence, suggesting they felt both situated in the virtual setting and aware of others' presence. While scores were slightly more variable for items like *Images vs Real Place* and *Virtual vs Somewhere Else*, the data still indicate a moderately strong sense of realism and immersion. Notably, despite a few low outliers, the overall pattern reflects a successful induction of presence across multiple facets. Figure 24 summarizes participants' responses to a presence questionnaire (Figure 25) assessing their subjective experience in the virtual environment.

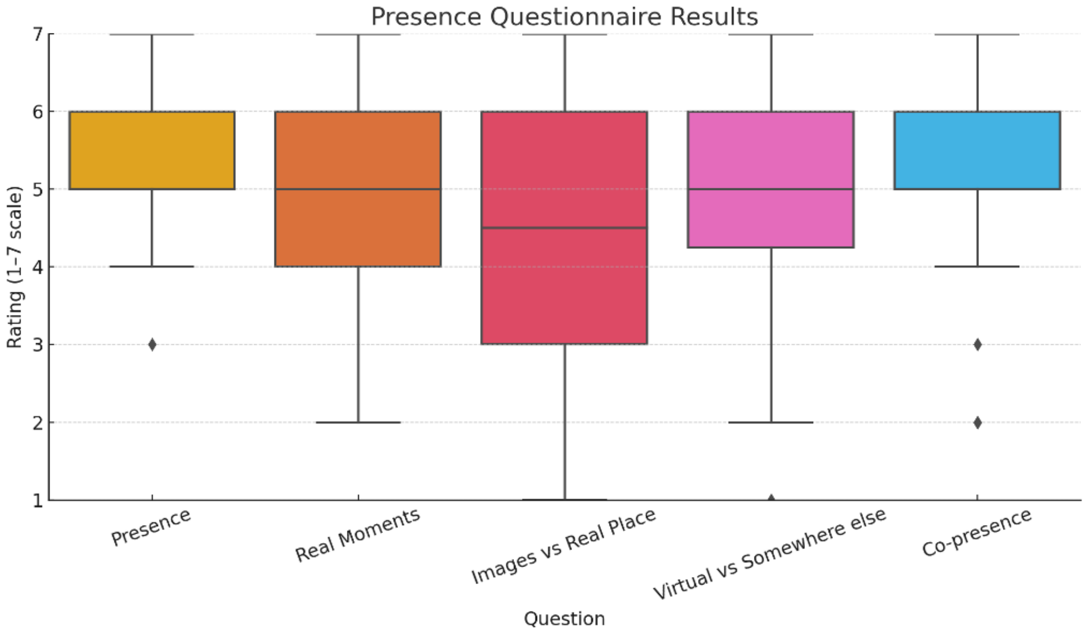


Figure 24: Presence Questionnaire Results

1 **Presence**: Rate your sense of being in the virtual environment

2 **Real Moments**: To what extent were there moments during the experience when the virtual environment was your reality?

3 **Images vs Real Place**: When you recall your experience, do you think of the virtual environment more as images you saw or as a place you visited?

4 **Virtual vs Somewhere else**: During the experience, which was stronger overall: your sense of being in the virtual environment or being somewhere else?

5 **Co-presence**: To what extent did you feel like you were in the same space with other people?

Figure 25: Presence Questionnaire questions

Self-report of teamwork and social experience during experiment

This bar chart below (Figure 26) presents participants' self-reported ratings of their teamwork and social experience during the task. Responses reflect a generally positive social dynamic, with high agreement on statements like *"We communicated well as a team", "I enjoyed contributing to our success"* and, *"Winning together gave me a warm and satisfying feeling"*, all averaging around 5 or higher on a 7-point scale.

While most positive items received strong endorsement, negative statements such as *"I would have preferred to do the task alone"* and *"I felt bored while playing"* were rated notably lower, indicating disagreement. Still, some moderately high ratings on items like *"I felt frustrated during the task"* and *"I was annoyed by how my teammates played"* suggest moments of tension or difficulty.

Overall, the results indicate that participants valued the collaborative nature of the task, found it emotionally rewarding, and largely experienced the activity as a cooperative and engaging group effort, despite occasional frustration or interpersonal discomfort.

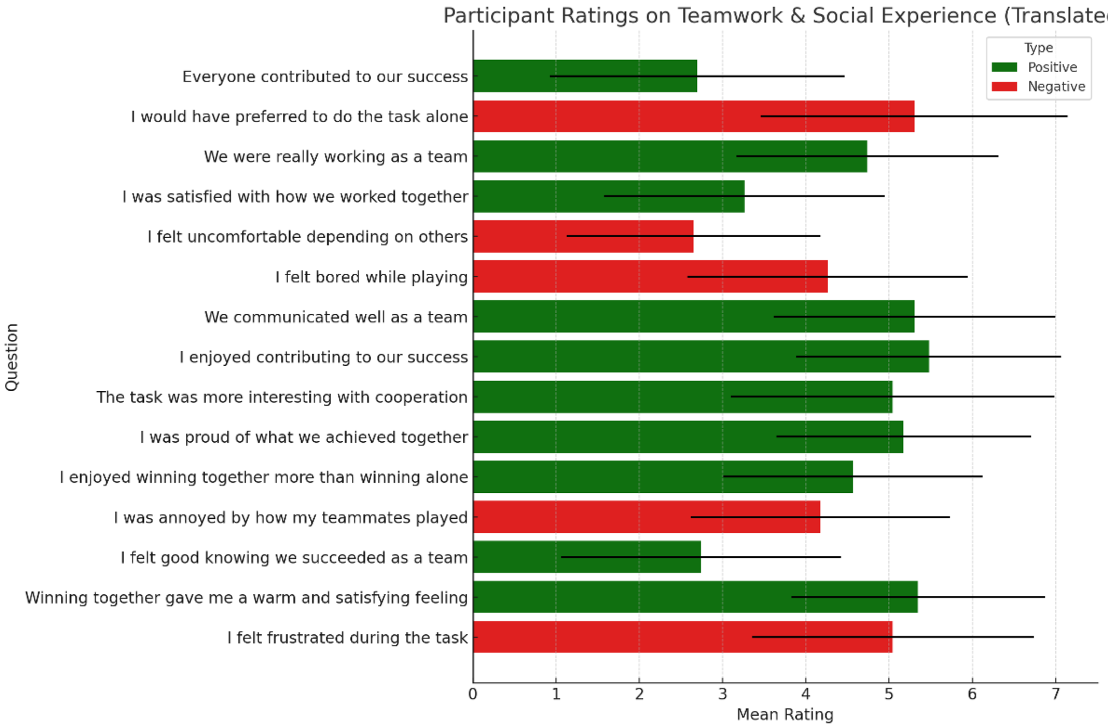


Figure 26: Participant Ratings on Teamwork & Social Experience

This version of the study provides a rich behavioral and gaze-based dataset to assess co-presence, place illusion, and plausibility before launching the EEG variant. By exploring eye contact, attention to teammates, and participants' self-reported sense of teamwork and presence, the experiment develops a multi-level framework for evaluating social immersion. In particular, the combination of gaze behavior, self-report, and performance allows us to isolate moments of successful collaboration, helping operationalize presence and social connection in gameplay.

Next steps

The next steps involve a multi-method analysis pipeline. First, exploratory analysis of eye-tracking data will be conducted, followed by examining correlations between gaze duration, both toward other players and between them, and game performance. In parallel, participants' gameplay strategies will be modeled. Based on insights from these analyses, the EEG study analysis plan will be refined, culminating in the implementation of the full EEG study itself.

3.4.3. Sensorimotor Contingencies and Eye Scanpath Entropy

The study, conducted at the University of Barcelona, explored how changes in sensorimotor contingencies influence the feeling of presence in VR. 30 participants were involved, although due to technical issues, the final analysis included data from 26 participants for the main task and 29 for the eye scanpath entropy analysis. The full version of this work has been published in [Ref. 14].

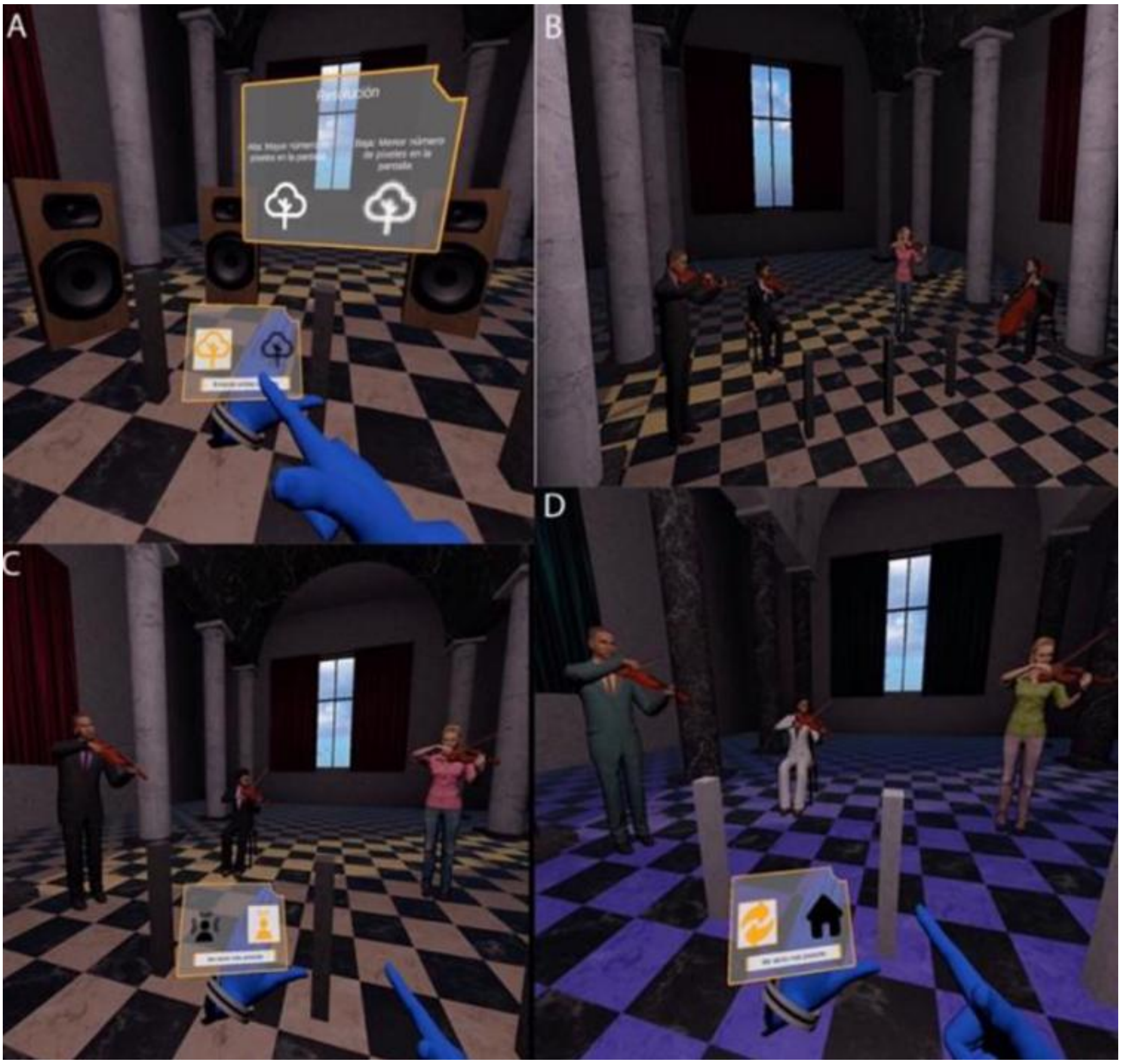


Figure 27: String quartet classical music performance in VR

Participants experienced a VR scenario depicting a classical music performance by a string quartet (Figure 27), viewed through a Pico Neo 3 Eye head-mounted display. The experiment used the A3M and a reinforcement learning agent [Ref. 15]. In this VR setup, the VE could be altered along several binary factors and participants were repeatedly presented with sequential options. For each proposal, they were asked to choose the option that they felt would increase their experience of "being there".

Initially, the reinforcement learning (RL) agent proposed these changes randomly, but as participants made their choices, the RL algorithm updated its model. This learning process enables the RL agent to increasingly offer configurations that participants find preferable, ultimately converging towards an optimal set of environmental settings that maximized each participant's sense of presence.

Alongside these preference-based adjustments, eye-tracking data was collected to examine eye scanpath entropy. Results showed that as the RL agent refined the environment, participants' gaze patterns became more focused and predictable over time (decreasing eye scanpath entropy).

Importantly, lower entropy correlated with higher self-reported subjective ratings of Place Illusion (PI) scores in post-session questionnaires. When asked to rank the importance of manipulated factors, participants consistently rated resolution as the most impactful for enhancing presence, while color was considered the least significant.

Overall, the findings provide both subjective and objective evidence that sensorimotor contingencies strongly influence the sense of presence in VEs.

3.4.4. Elephant in the Room study

The Elephant in the Room study [Ref. 16] was conducted at the Event Lab (University of Barcelona) between 2024 and 2025 with 29 participants. The aim was to investigate whether participants experience greater stress in Mixed Reality (MR) compared to VR when exposed to identical threatening scenarios – such as encountering a wolf.

This study utilized a modified version of the A3M method originally developed by Küçüktütüncü et al. [Ref. 14]. In the original approach, participants periodically adjusted features of a virtual environment – such as toggling between mono and stereo rendering or altering color schemes – while a RL agent learned their preferences over time. Participants' decisions were then analyzed using Markov chains to identify probabilistic preferences related to the sense of presence. For the present study, the RL agent was replaced with an Adaptive Thompson Sampling agent, commonly used for efficient exploration in decision-making tasks. This change significantly accelerated development while maintaining effectiveness. This optimized A3M method will also serve as the backbone for the future presence evaluations of how the different PRESENCE technologies – such as haptic gloves and different avatar representations – influence the sense of presence in VR.

Participants were seated facing a virtual animal and could use a virtual tablet to accept or reject proposed changes in the scenario. The adjustable elements of the scenario, as depicted in Figure 28below, were:

- Animals: wolf (I), dog (H), rabbit (G), squirrel (F)
- Environments: Mixed Reality real room (A), a virtual replica of the same room (B), or a virtual living room (C)
- A Newton's Cradle (off, D)
- A Newton's Cradle (on, E)

Figure 28: Scenario conditions included

This created a total of 24 potential configurations, which participants could explore over two blocks:

1. Increase stress: always choose the option(s) that would make the scene more stressful.
2. Decrease stress: always choose the option(s) that would make the scene less stressful.

Table 14 shows the equilibrium probabilities derived from the Markov chain analysis of participant choices in the Increase Stress and Decrease Stress blocks (see also Adjuncts' sections 8.8-8.11). These values represent the long-run likelihood of each configuration being selected, based on all transitions observed across trials. Higher probabilities indicate configurations toward which participants consistently moved when trying to increase or decrease their stress.

Increase Stress Blocks	prob	Decrease Stress Blocks	prob
[Wolf, MixedReality, TRUE]	0.253	[Dog, AlternateRoom, FALSE]	0.169

[Wolf, ExperimentRoom, TRUE]	0.224	[Dog, AlternateRoom, TRUE]	0.119
[Wolf, MixedReality, FALSE]	0.097	[Squirrel, AlternateRoom, FALSE]	0.092
[Rabbit, MixedReality, TRUE]	0.093	[Squirrel, MixedReality, FALSE]	0.082
[Wolf, ExperimentRoom, FALSE]	0.062	[Wolf, ExperimentRoom, TRUE]	0.073
[Dog, ExperimentRoom, TRUE]	0.058	[Dog, MixedReality, FALSE]	0.053
[Rabbit, ExperimentRoom, TRUE]	0.053	[Rabbit, ExperimentRoom, TRUE]	0.051
[Wolf, AlternateRoom, TRUE]	0.044	[Wolf, MixedReality, FALSE]	0.050
[Dog, MixedReality, TRUE]	0.028	[Rabbit, AlternateRoom, FALSE]	0.049
[Rabbit, AlternateRoom, TRUE]	0.020	[Rabbit, MixedReality, FALSE]	0.034
[Rabbit, ExperimentRoom, FALSE]	0.013	[Wolf, MixedReality, TRUE]	0.033
[Squirrel, AlternateRoom, TRUE]	0.012	[Wolf, AlternateRoom, TRUE]	0.032
[Rabbit, MixedReality, FALSE]	0.011	[Squirrel, AlternateRoom, TRUE]	0.023
[Squirrel, AlternateRoom, FALSE]	0.010	[Rabbit, MixedReality, TRUE]	0.023
[Squirrel, ExperimentRoom, TRUE]	0.006	[Dog, MixedReality, TRUE]	0.021
[Squirrel, MixedReality, TRUE]	0.003	[Rabbit, ExperimentRoom, FALSE]	0.020
[Dog, AlternateRoom, TRUE]	0.003	[Wolf, AlternateRoom, FALSE]	0.014

[Wolf, AlternateRoom, FALSE]	0.003	[Rabbit, AlternateRoom, TRUE]	0.013
[Rabbit, AlternateRoom, FALSE]	0.002	[Dog, ExperimentRoom, TRUE]	0.012
[Squirrel, ExperimentRoom, FALSE]	0.002	[Squirrel, MixedReality, TRUE]	0.010
[Dog, MixedReality, FALSE]	0.002	[Squirrel, ExperimentRoom, FALSE]	0.010
[Squirrel, MixedReality, FALSE]	0.001	[Wolf, ExperimentRoom, FALSE]	0.008
[Dog, AlternateRoom, FALSE]	0.000	[Dog, ExperimentRoom, FALSE]	0.008
[Dog, ExperimentRoom, FALSE]	0.000	[Squirrel, ExperimentRoom, TRUE]	0.001

Table 14: Equilibrium Probability Distributions

In parallel, subjective stress rankings for each configuration were collected with rankings from 1 (most stressful) to 12 (least stressful) displayed in boxplots (Figure 29). The thicker horizontal lines are the medians and the boxes are the interquartile ranges (IQR). The bottom whisker extends from the lower quartile (Q1) to the lowest data point that is within 1.5´IQR from Q1. The top whisker extends from the upper quartile (Q3) to the highest data point that is within 1.5´IQR from Q3.

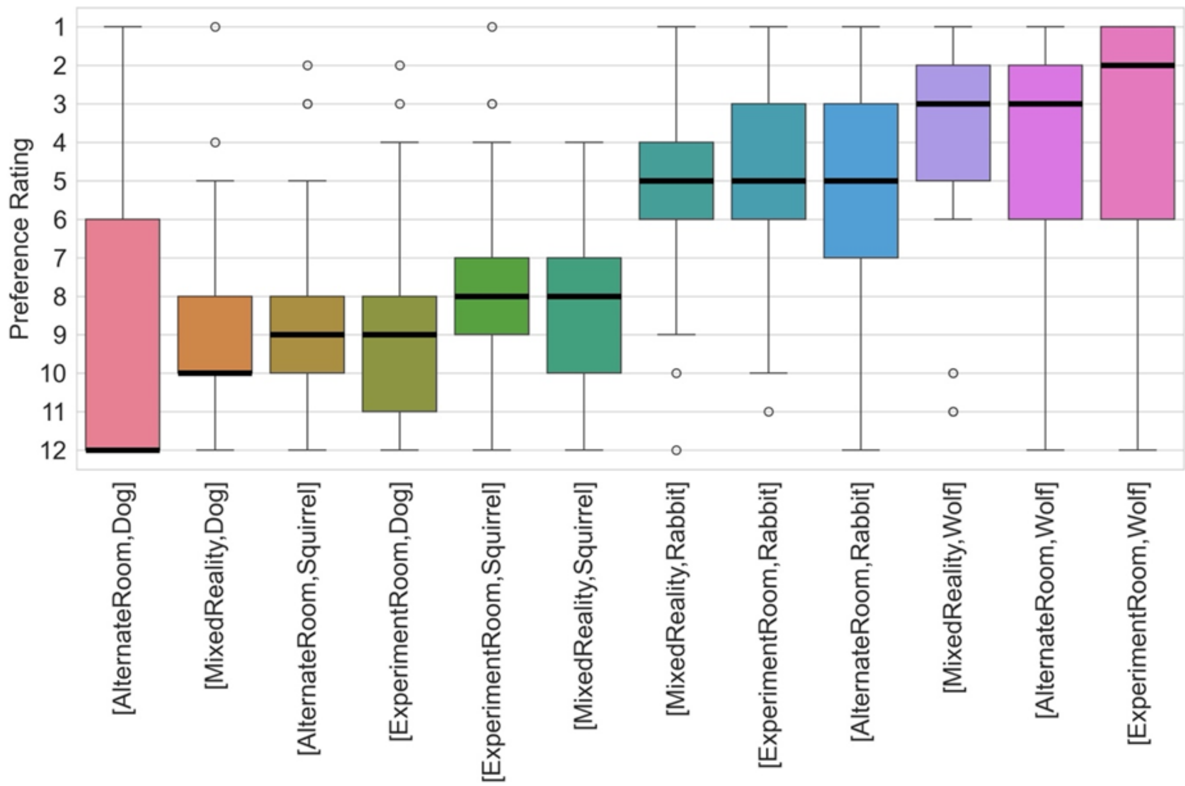


Figure 29: Box plots of the preference ranking of the configurations

The results demonstrate that MR scenarios with threatening animals, particularly a wolf, were experienced as the most stressful, and actively avoided these when trying to reduce stress. These findings suggest that MR can elicit greater emotional responses than VR in equivalent contexts, likely because the threat appears integrated into the real physical surroundings rather than an entirely virtual world. This has significant implications for the design of immersive technologies, especially as MR becomes more accessible and realistic.

The A3M in combination with Thompson Sampling proved effective in discerning subtle participant preferences without overwhelming them, indicating its value for efficiently evaluating complex multi-factorial scenarios in immersive studies.

3.4.5. Ethical Issues of Impersonation and AI Fakes in Social Virtual Reality

In the context of IEEE VR 2025, an experiment was conducted focusing on ethical concerns regarding identity impersonation and AI-generated virtual humans within social VR, aligning closely with one of the PRESENCE project's core objectives to explore and address ethical challenges arising from XR technologies. The experiment featured a live panel discussion set in a historically themed VE modeled after Bletchley Park, where participants appeared as look-alike virtual avatars (see Figure 30). The event was broadcast to an audience of over 100 attendees via a large video screen. The full version of this work has been published in [Ref. 17].

Notably, two panelists deliberately swapped their avatars mid-discussion, attempting to convincingly embody each other's identities. Additionally, the panel featured an AI-driven virtual avatar representing Alan Turing, controlled via a large language model (ChatGPT4o). Figure 30 shows the virtual room where the discussion took place with A) an overview of the room showing all the panellists; (B) the moderator speaking – note also the view through the window; (C) the spatial relationship between the moderator and Alan Turing; (D) the Alan Turing avatar speaking.

Figure 30: The virtual room where the discussion took place

The study primarily aimed to evaluate if audience members could detect the deliberate avatar swap and assess their perceptions of the AI panelist's realism, ethical appropriateness, and overall contribution to the discussion. Among the 100 attendees who completed a post-panel survey, around 40% failed to notice the avatar swap, indicating significant change blindness regarding social identity within VR.

The Alan Turing avatar provoked extensive ethical debate, notably regarding representation, realism, and interaction boundaries in VR. Audience feedback highlighted that while technologically impressive and effective in conversational interaction, the avatar raised critical ethical concerns about realistically and respectfully portraying historical figures. Participants found the AI-driven Alan Turing avatar less realistic and somewhat distracting, yet its presence clearly demonstrated the increasing capabilities of generative AI in natural conversational contexts within VEs.

These results highlight the crucial need for awareness and proactive measures against identity deception and ethically sensitive representation issues, essential for advancing XR technologies responsibly.

3.4.6. Impact of 360° VR compared with a 2D screen display

This study explored how immersive VR can influence emotional engagement and attitudes toward marginalized social groups. Specifically, the experiment compared participants' responses to a documentary about undocumented young migrants to Spain, when viewed as a 360° 3D video versus the same content presented on a simulated 2D screen. Both conditions were experienced via the same HMD, ensuring hardware consistency. The full version of this work has been published in [Ref. 18].

51 participants took part in the study (23 in the immersive 360° video condition and 28 in the 2D screen condition). After viewing the documentary, participants wrote short essays, which were analyzed for sentiment. Results showed that those who experienced the 360° condition expressed significantly greater emotional involvement. Their responses reflected more intense empathy, stronger connections to the individuals portrayed, and more nuanced reflections on the societal challenges faced by MENA individuals.

This experiment illustrates how immersive VR can go beyond traditional media by fostering deeper affective responses and a stronger sense of "being there." These findings align with PRESENCE's goal of understanding and improving different dimensions of presence, particularly **plausibility** and **social co-presence**. This highlights the relevance of immersive documentary storytelling as a tool for ethical awareness and public understanding.

3.4.7. Confusion between VR and reality

This study was conducted at the Event Lab (University of Barcelona) between 2024 and 2025 to explore the extent to which experiences in VR can be mistaken for real-life events. The study was conducted over two sessions with a total of 49 participants. The full version of this work was published in iScience in 2025 [Ref. 19].

In the first session, participants were immersed in a virtual environment that was a replica of a real experimental room (Figure 31B). Inside the virtual environment, they interacted with a virtual experimenter (Figure 31C and D) – an avatar whose speech was subtly manipulated to either support or express skepticism about climate change science.

During the VR interaction, participants were invited to sit on a virtual chair and observe a tablet being placed in a cabinet drawer. Subtle variations in the virtual experimenter's dialogue reflected either support for or skepticism of climate change science. Before and after the VR session, participants completed an Implicit Association Test (IAT) to examine implicit biases about gender and attitudes towards climate change.

One week later, participants returned for a second session, which took place in the real version of the same room (Figure 31A). Here, a real experimenter behaved as if the tablet was missing, which was done to assess whether participants transferred virtual memory to the real environment.

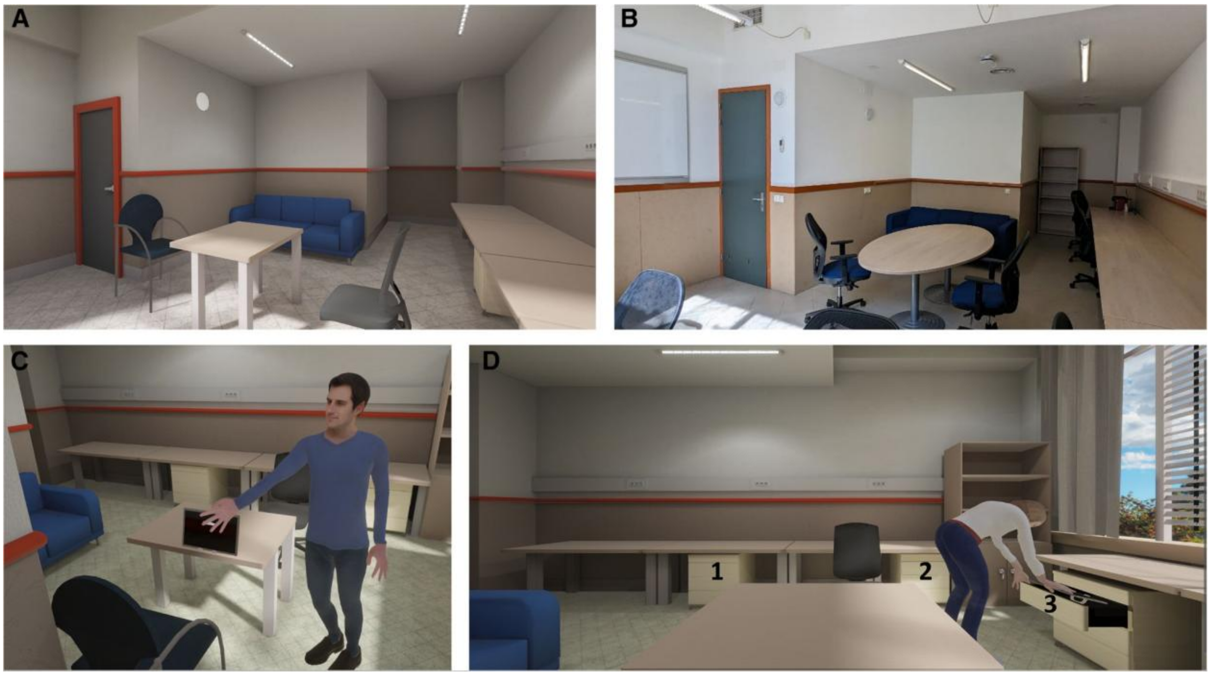


Figure 31: The experimental setup

The study employed a mixed-methods approach, combining behavioral observation, self-report measures, and Bayesian statistical modeling to estimate the population-level effects across ten outcome variables. The IAT measured implicit associations between gender and attitudes toward climate change, with scores compared before VR, immediately after, and one week later.

Results showed that 20% of participants sat on the virtual chair without checking for a real one, and 45% later used information from the virtual environment to locate the tablet in reality. Moreover, subtle changes in the phrasing of questions by the virtual experimenter influenced participants' IAT scores a week later, particularly in conditions where the experimenter expressed a belief in or skepticism toward climate change. All data and analyses can be found in [Ref. 20-Ref. 24].

These findings raise ethical concerns about how strongly people can internalize virtual experiences and mistake them for reality.

3.4.8. Social Presence with autonomous characters

Autonomous virtual characters are avatars that talk and move on their own without being controlled by a VR user. While creating plausible interactive behavior for such characters is a longstanding challenge, research shows that VR users do attribute human-like qualities to them, despite being told they are autonomous and despite showing very crude interactive behavior.

One aspect that is specific to immersive virtual environments is embodied social interaction, i.e., the fact that immersive technologies can recreate the illusion of physical proximity typical of everyday social life. However, the character animation techniques that are readily available for VR development derive from the videogame industry and are not particularly suited for characters moving and engaging in social conversations in proximal space.

A promising alternative comes from physics-based humanoid animation, which can offer more general interactive capabilities respecting physical constraints, compared to traditional animation approaches.

The objective in this project is to improve existing character animation techniques, and particularly physics-based control methods, more adapted to the specific needs of VR experiences to deliver more convincing embodied social interaction with autonomous interactive characters.

So far in WP4, two techniques from the field of physics-based animation – DReCon[5] and DeepMimic[6] – have been reimplemented into VR production environments, ensuring they can be deployed directly within Unity-based projects. A third method, AMP[7], is currently being adapted and developing a faster, more robust, and more scalable deep reinforcement pipeline for training these controllers. Once this technical groundwork is achieved, the aim is to push the state of the art in physics-based animation to better support the specific demands of embodied social interaction in VR. To evaluate the impact of adopting these techniques the following experiments are planned:

Proxemics study

This experiment will investigate personal space and approach behavior in VR. In a collaboration between UHAM and ARTANIM, participants will be asked to approach a virtual character to read a word displayed on its T-shirt. The virtual character will be presented in four different versions, each varying in its level of behavioral reactivity. Two versions will employ traditional animation techniques, while the other two will use physics-based control methods.

The primary focus of the experiment will be on behavioral measures to assess whether users spontaneously respect social distances when interacting with virtual characters, and whether the animation method influences this behavior. Key behavioral metrics will include:

- Task completion time
- Spontaneous conversational engagement with the virtual character
- Approach velocity
- Frequency or duration of eye contact

[5] https://dl.acm.org/doi/abs/10.1145/3355089.3356536

[6] https://dl.acm.org/doi/10.1145/3197517.3201311

[7] https://dl.acm.org/doi/10.1145/3450626.3459670

These behavioral observations will be supplemented by post-experiment questionnaires assessing participants' sense of presence and social presence in the virtual environment.

Animation fidelity study

While physics-based humanoid controllers excel at complex and adaptive movement – such as diverse physical interactions, variable door sizes, or objects of differing weights – VR production environments require animations that are not only flexible but also reliable and compatible with existing animation pipelines. This study will focus on developing objective measures of animation fidelity, assessing:

- How easily physics-based controllers can be integrated into standard character animation workflows
- How accurately they can reproduce an actor's internal emotional state as expressed through movement (e.g., sadness, joy, or other affective cues).

Contribution to presence

Finally, the University of Barcelona and ARTANIM will integrate these novel animation techniques into the museum experiment, evaluating how different animation methods contribute to the overall feeling of presence in VR.

3.4.9. The role of IVA on Emotional Contagion, Conformity, and Opinion Shaping

This study examined the influence of IVAs on user opinions in a virtual stand-up comedy club, focusing on the socio-psychological mechanisms of emotional contagion and group conformity. The research combined these two areas within a novel experimental framework. This work was a collaboration between UHAM, UB, and ARTANIM. The full results have been submitted to the IEEE International Symposium on Mixed and Augmented Reality (ISMAR) and are under review. This section below reports only the sense of presence results measured at the end of the study.

An exploratory pilot study was conducted with 20 participants, who rated the funniness of jokes in VR under varying conditions of virtual agent laughter: absence, medium intensity, and strong intensity. The number of IVAs seated at the same virtual table as the participant was also varied. At the end of each session, the sense of presence was measured using a standardized IPQ questionnaire. In the virtual environment, participants sat at a table with one or more IVAs displaying different intensities of laughter in response to the jokes delivered by the virtual comedian on stage. A virtual sheet of paper was available on the table for the participant to rate each joke's funniness (See Figure 32).

Figure 32: IVHEmotionalContagion

IPQ

The IPQ questionnaire was used to measure the sense of presence experienced in a virtual environment. It consists of 14 items divided into 4 subgroups: Spatial Presence, Involvement, Experienced Realism, and the Sense of Being There. Each of the items was rated on a 7-point Likert scale (0–6), ranging from Fully disagree to Fully agree, and Did not feel present to Felt present.

Following the method developed by Tran et al. [Ref. 25], results were transformed to a scale of -3 to +3 and compared to established percentile thresholds, classified as:

- Low [-3.00, 0.28]
- Moderate [0.28, 0.73]
- High [0.73, 1.07]
- Very high [1.07, 1.30]
- Exceptional [1.30, 3.00]

The results indicate that Spatial Presence was very high (M = 1.08, SD = 1.09), involvement was high (M = .79, SD = 1.11), and the general Sense of Being There was moderate (M = .6, SD = 1.50). However, it was found that Experienced Realism was low (M = -.64, SD = 1.07) and the overall presence score was moderate (M = .47, SD = .87).

3.4.10. Presence evaluation survey – across activities

As summarized in Table 13 (see section 3.3.1), several of the user studies included the IPQ and/or the Social Presence Questionnaire to assess the sense of presence, also with other users and IVAs involved. When applied, participant numbers from those studies were also counted toward **T1.4 Presence Evaluation** and **KPI 1.3**:

> *Create a novel methodology for evaluating social and co-presence at four (4) levels, such as place illusion, plausibility, body ownership, and co-presence, analysing the impact of the new*

technologies and UCs, relying on experimental studies encompassing, at least, 150 participants (WP1, T1.4, D1.3).

The studies incorporating the IPQ and/or Social Presence Questionnaire were:

- **First Playable App Evaluation** – 23 participants
- **V.0 PRESENCE App Evaluation** – 18 participants

In total, these activities involved 41 participants, contributing directly to KPI 1.3. Detailed findings for each study are reported in Section 3.3.

3.4.11. Holographic Communications: Subjective Experience Evaluation

This study focused on evaluating a holographic video conferencing setup, referred to as the Holographic Studio, within a professional studio setting. This setup enabled real-time communication using volumetric video (point cloud) representations of participants in a shared virtual space. The study was conducted with professionals from the creative sector, specifically in the context of television production with the aim of assessing communication quality, social connectedness, and immersion. Participants engaged in a live holographic interaction section and completed several questionnaires afterward. The detailed results are reported in [Ref. 26], and this section presents only a high-level summary of the findings related to social connectedness and immersion (see Adjuncts' Section 8.12).

Social Connectedness and Co-Presence

To understand the feeling of being together in a shared virtual environment, participants were asked to rate:

- Perceived co-presence
- Emotional closeness
- Sense of shared attention

The results demonstrate that the presented technology and VR scenario successfully fostered a sense of social connectedness and togetherness. Participants reported a strong sense of being together in the same space, despite being physically apart. The shared experience was described as pleasant, immersive, and focused, with minimal distraction. Several participants noted that the experience felt genuine, and not superficial, rather they described it as having created a pleasant, shared memory.

Immersion and Presence

Immersion was also assessed in terms of:

- Feeling of being physically present
- Involvement in the session
- Environmental realism

The results confirm that the presented technology and VR scenario delivered satisfactory levels of presence and immersion. Participants reported feeling fully focused on the experience, were able to ignore external distractions, and some perceived the duration of the experience as shorter than it actually was.

3.5. System Ethics, Trust & Privacy

This task aims to identify gender, ethical, trust and privacy related issues to guide the creation of PRESENCE technologies, where in the first year of the project, UC partners have created a 'first playable app' to give end users a first experience of the technology. The activities under this task were conducted during phase II of the project (D1.1, p.27, section 4). Between M07-M18, qualitative research (workshops and interviews) following the walk-through method and a think-aloud protocol (D1.1, p.26, section 3.2.5) have been conducted, where end users have been invited to give feedback on potential ethical considerations of the 'first playable app' and the UC scenarios with fully integrated UC apps.

The expected outcomes of this task are:

- a systematic overview of possible uses for XR technology in highly contextualised scenarios to anticipate ethical issues in the development;
- an overview of different ethical themes organised by technology, UC and stakeholders so that developers can leaf through these themes to check if there are relevant themes;
- and the delivery of the ethics, trust and privacy strategy (by M18 in D1.2), describing the use of ethics, privacy and General Data Protection Regulation (GDPR) forms for a safe process involving end-users in the two demonstrators.

First, the testing activity of the 'first playable app' will be presented, where the methodology of the workshops and interviews conducted and results per UC are outlined. Then, the prioritisation workshop held with the consortium will be outlined, starting by presenting the methodology used as well as the results gathered. Finally, the system ethics, trust and privacy strategy will be presented.

3.5.1. First Playable app testing

This activity was joint with UC and requirements definition & validation (T1.2) and User Centric Approach and UX testing (T1.3), to read more about the methodology used and the feedback gathered through these tasks, see Section 3.2.3 and 3.3.3. The participants targeted were anyone over 18 years old and who had an interest in any of the UCs, those who signed up were mainly students and colleagues from IMEC-SMIT and the Vrije Universiteit Brussel.

Methodology

As part of this activity, we wanted the participants to reflect on ethical considerations of the app they had tested before the workshop, but also to ideate further on potential ethical considerations of the technical pillars of the project when they've been integrated. Thus, after having given feedback on their first impressions, the participants were shown a video explaining and demonstrating the technical pillars of the project to better understand what these will do for the UC apps.

Then, the researchers asked questions as demonstrated in Table 15 to explore what potential ethical considerations there might be. Based on this discussion, the participants were asked to pick one aspect that they deemed important to further explore, this aspect was then the main area of which the participants ideated solutions (see Figure 33).

1. What types of people or groups do you think might find this experience easy or enjoyable to use?

2. What types of people or groups do you think might struggle with it or feel left out?
3. If this experience would be collecting the data of the different user roles in this scenario, what kind of information do you think the experience would be collecting about them? → What kind of information do you think the experience would be collecting about each user (end user and professional) in different locations? **(For cultural heritage UC: tour guide; what if it would be a holoported expert?)** - E.g. for UC2.2 a memorial site vs at home.
3. What could be some barriers - physical, technical, or cultural - that could prevent someone from fully enjoying or using this experience? → E.g., the different personas of the UC 4. What could be an example of something in this experience that might feel unfair or exclusive? → E.g., are there any elements of the experience that favor certain groups or that create friction/discomfort for certain people/groups?

Table 15: Guidance Questions for Exploration of Ethical Considerations

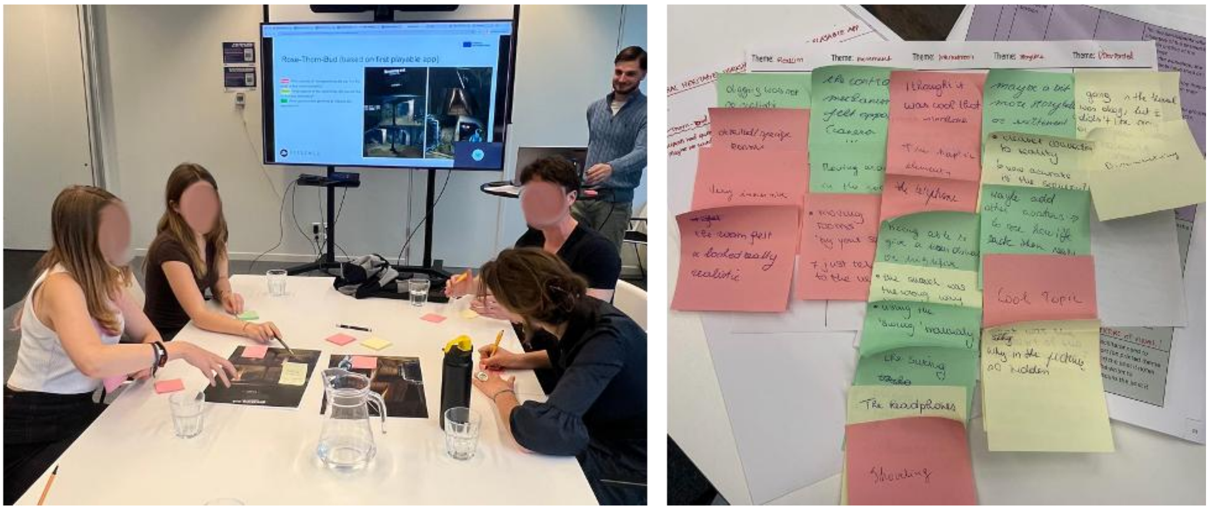


Figure 33: Ideation Exercise Ethical Considerations and Solutions (Workshops)

As mentioned in Section 3.2.3, we had to revise the format of the sessions to **in-depth interviews**. For the questions exploring ethical considerations of the app and project technologies, they remained the same as in the previous workshop format (see Table 16).

1. What types of people or groups do you think might find this experience easy or enjoyable to use? - What types of people or groups do you think might struggle with it or feel left out?
2. If this experience would be collecting the data of the different user roles in this scenario, what kind of information do you think the experience would be collecting about them? - What kind of information do you think the experience would be collecting about each user (end user and professional) in different locations? **(For cultural heritage UC: tour guide; what if it would be a holoported expert?)** → E.g. for UC2.2 a memorial site vs at home.
3. What could be some barriers - physical, technical, or cultural - that could prevent someone from fully enjoying or using this experience? - E.g., the different personas of the UC

4. What could be an example of something in this experience that might feel unfair or exclusive?
   - E.g., are there any elements of the experience that favor certain groups or that create friction/discomfort for certain people/groups?

Table 16: Guidance Questions for Exploration of Ethical Considerations (Interviews)

Results per UC

The main themes that emerged from these sessions revolved around accessibility & inclusivity, privacy & data transparency, cultural & historical integrity, and realism & functionality. From these main themes, a number of subthemes emerged, which can be consulted in Table 17 below.

Although these subthemes tend to be the same across UCs, it can be seen that these ethical considerations had different meanings to the participants based on the app they tested. In this first version of the apps, the participants were not able to experience the technical pillars (holoportation, haptics, and intelligent virtual agents), but after having explained the intended use of these in each UC, participants were asked to envision what potential ethical considerations could arise from their integration, so that we can already consider this throughout the technical development.

Theme	Professional collaboration	Manufacturing training	Health	Cultural heritage
Accessibility and inclusivity	Hardware access, onboarding support	Cost, space, VR sickness, mobility, language barriers	Sensory needs, control options, onboarding	Adjustable settings
Privacy and data transparency	Body scan privacy concerns	Surveillance stress, tracking fears	Transparency on biometric/emotional data	Clear data transparency
Cultural and historical integrity				Accurate and respectful storytelling
Realism and functionality		Realistic graphical depictions, realistic interaction	Realistic simulation of real world in virtual environment	

Table 17: Overview of ethical themes

UC1.1 Professional collaboration

In the context of professional collaboration, participants mentioned that equity of access is a significant concern, as if the equipment needed is too expensive, the experience will be financially inaccessible to a large group of people. They argued that even though the main target group for this kind of application would be companies, they would still need to ship hardware to employees to use in those instances they cannot have these types of design meetings in person, which can end up being expensive and possibly privacy intrusive as employees would have the setup in their private homes. In the case of the latter, the participants were concerned about what kind of data or imagery may be collected and how it would be stored, as well as who has access to it (employers and/or AI?). It was also mentioned the importance of equal representation of people of all ethnic backgrounds, and that all users of the app and technology can use and accurately feel interactions in the virtual environment, e.g., with the haptic gloves and vest.

UC1.2 Manufacturing training

In the domain of manufacturing training, many ethical issues mirror those in collaboration but with domain-specific nuances. Here, participants were worried about high costs for hardware, which might pose barriers for widespread adoption. VR- or cybersickness was also mentioned as a potential barrier, as some people might experience this differently it can have an impact on performance, meaning that if users spend too much time in the environment, they may not be able to complete the training program. As the app targets a wide group of end users (trainees) within different manufacturing companies, they may need to content to be translated to their respective language, here participants envisioned that if the translations are inaccurate or limited (e.g., if someone has to complete the training in their second or third language), users may learn procedures incorrectly or miss out on crucial information. Another relating aspect mentioned by participants is surveillance stress, wherein users may feel stressed by knowing that their performance is recorded somewhere and that someone is watching them. Participants mentioned that this may lead to users making mistakes or lose focus, and that it is important to be transparent about how data is collected and used so that users don't have to worry. In terms of realism and functionality, participants voiced concerns about how realistic or graphic representations will be of dangerous practices. Regulation around trainee misconduct or system abuse also emerged as a key concern.

UC2.1 Health

In the health UC, ethical considerations mainly revolved around the vulnerability and diversity of end users. Here, participants stressed that devices must be physically accommodating to a wide range of patient needs, e.g., for patients with disabilities or neurodivergent conditions. In some of the sessions, participants envisioned the app's impact on health care workers and stressed the importance of procedural efficiency, especially for brief routine procedures such as blood drawing, suggesting that perhaps this sort of app would be better suited for longer procedures, such as cancer treatment or while in a waiting room. Accurate and synchronized visual representation during procedures (e.g., blood draws) was also emphasized to maintain immersion and reduce anxiety.

UC2.2 Cultural heritage

For the cultural heritage UC, participants stressed the importance of accurate and respectful storytelling, saying that it's important to not romanticize or distort sensitive topics. Participants had also mentioned that they had felt a bit of cybersickness as some parts of the experience required different physical movements throughout the experience which also caused them to feel disoriented at times. This they flagged could be potentially exclusive or distressing for some users, e.g., with physical or neurodivergent conditions. Additionally, concerns around data tracking, privacy, and how AI or recording tools might be used were also widely discussed.

Across UCs

Across all UCs, several ethical themes recur, albeit with contextual nuances. Accessibility is a universal concern, especially in terms of hardware, UX, and usability, highlighting the need for inclusive design, especially in terms of mobility and limitations, as the end users may not be able to fully move or enjoy the experience due to physical or neurodivergent conditions. Onboarding support and clear instructions are essential across all domains, especially since not all intended end users might be as tech savvy or used to VR as others. To ensure that all intended users feel included and capable, participants suggested adding adjustable settings, where users can adjust the experience to their needs, e.g., in terms of difficulty levels, volume settings, more or less instructions, etc. Finally, data privacy, transparency, and AI access are pressing across the board, underscoring the need for clear regulation and user control.

3.5.2. Ethical themes consortium prioritisation workshop

The aim of this activity is for the consortium to, through a prioritization workshop organized by IMEC, decide which ethical challenges and opportunities are relevant for and/or beyond the scope of the project. The expected outcome of this workshop is a list overview of different ethical themes organized by technology, UC, and stakeholder, which project developers can use in the further development of the technologies to see which themes they should consider throughout the project. This list overview is planned to also be included in the overall system ethics, trust and privacy strategy.

Method

For this activity, a 1-hour workshop was set up with consortium partners to together discuss potential solutions or mitigation strategies to the ethical considerations found from the user tests. In this workshop, the feasibility of each ethical consideration was also discussed, mainly around how feasible it is for the responsible partner to integrate and consider this during the project lifetime or whether some would be considered in the exploitation plan. During the workshop, the following questions were asked:

- How might we overcome these ethical issues?
- How feasible are these ethical considerations and solutions to implement in the project?
- Who will do what and when?

All consortium partners were invited to participate, and a Doodle was sent for everyone to fill out their availability. Due to June being a busy time for several partners, not every partner was able to participate and be represented in the workshop. To still include them, the results from the ethical theme workshop were shared with everyone. During the General Assembly in Amsterdam (June 2025), the results were also presented, giving an opportunity to further discuss.

Results

In the workshop, the floor was open for everyone to discuss and suggest potential solutions to the ethical themes found from the user testing sessions. In Table 18 below, an overview of each theme and solutions can be found (see also Adjuncts' section 8.13). During the workshop, some consortium partners also took the opportunity to think about what other potential ethical considerations that may arise for other stakeholders, such as AI system providers/operators, see full table in Adjuncts section 8.13. Unfortunately, there was no time left during the workshop to discuss these new considerations, but the discussion will proceed throughout the project.

Stakeholder	Theme	Subtheme	Summary ethical theme	SOLUTIONS PER USE CASE					Who	When
				Professional collaboration	Manufacturing training	Health	Cultural heritage	ALL UCs		
End user	Accessibility & inclusivity	Hardware access & cost	High costs for hardware equipment (high-end computers, gloves, vests, VR headsets, etc).					- PRESENCE technologies should also work even if you do not have access to all HW components - Investing in hardware as possible threshold for the institutions is something taken into account also in WP6 in exploitation plan - identify in PRESENCE what is the minimum set-up (what is mandatory and what is necessary) and how open is our SDK	**WP 2, 3, 4, 6**	**Phase 3 + exploitation plan**
		Physical limitations hardware	Some hardware items might not fit all users, e.g., sizing, disabilities.					- PRESENCE SDK should allow different HW types from different manufacturers (e.g. making bigger vests or smaller gloves)	WP 3	**Phase 3 + exploitation plan**
		Onboarding support	Extra support in set-up of system, how to use the system (controls, navigation, and task instructions), support throughout experience.					- including tutorial before each experience to train users with interactions and with hardware - support during experience (depending on UC) - UX of the applications should include modes for inexperienced users, and guide them if they get stuck at one part of it	UC partners + WP 2, 3, 4	**Phase 3**
		Mobility & limitations	Adapted VR experiences and hardware to users with physical limitations and phobias/autism/dementia, e. g., option to move with controls, ensure glasses fit comfortably under headsets, customization options of VR environment.					- ensure that multiple options for interaction are available	UC partners	**Phase 3**
		VR sickness	Cybersickness due to time spent in VR environment and/or actions causing disorientation.					- introduce less artificial motions, e.g., joystick-based; - inform user about symptoms at beginning, e.g., via display screen / informed consent	UC partners	**Phase 3**
		Representation	Equal ethnic representation for avatars.					- generate set of diverse avatars: ethnically, gender, body types, etc.	WP 4 (DIDIMO)	**Phase 3**
		Language barriers	Exclusion due to translation issues or lack of familiar/mother tongue languages.					- LLM can also be used to translate or simplify language	WP 4 (UHAM)	**Phase 3**
		Adjustable settings	Adjustable settings such as adding game-like elements, difficulty level options, volume settings...					- ensure that these options are available	UC partners	**Phase 3**
	Privacy & data transparency	Data collection, storage & use	Concerns about what data is collected, stored, and used. E. g., imagery, biometric data...					- provide informed consent screen at beginning of screen; - providing about/information through settings/preferences; - provide option to inspect data that is used by the system	UC partners	**Phase 3**
		Role of AI	Concerns about AI use and what it has access to.					- provide informed consent screen at beginning of screen; - providing about/information through settings/preferences; - provide option to inspect data that is used by the system	UC partners	**Phase 3**
		Surveillance stress	Concerns about to what extent trainees are "surveilled" by trainers, during or after sessions.					**If we collect data we need to provide access to user to decide what they want to happen to their data (e.g., delete)**	UC partners	**Explotation phase**
		Abuse & regulation	Regulations around misconduct and abuse, and how is this data"recorded" and handled.					**At the moment, no data is recorded, if that's the case we can start thinking about regulations**	All	**Explotation phase**
	Cultural & historical integrity	Accurate & respectful storytelling	Ensure accurate and respectful storytelling.				Disclaimer: is the experience historically accurate or is it fictional? When accurate provide some references		Zaubar	**Phase 3**
	Realism & functionality	Dangerous practices	Graphic depictions of consequences of actions.		No real depictions, but add warning message stating consequences or a sound or haptic feedback to signal the user should not do that action				Vection	**Phase 3**
		Realistic learning	Concerns about realistic learning.					Ensuring movement options for users alongside controllers	UC partners	**Phase 3**
		Virtual representation	Visual representations of real world in virtual world.			Possible to add option of 'pass through'			SyncVR	**Phase 3 / exploitation phase**

Table 18: Solutions and mitigations ethical considerations

<u>Accessibility & inclusivity</u>

The solutions under this theme mainly revolved around how the SDKs and UC apps can become more accessible and inclusive. Some ethical considerations that had emerged from the user tests concerned hardware-specific issues, which is not particularly something that the project consortium can solve easily, e.g., cost of hardware and sizes (as the latter depends on the availability of different sizes from the hardware company/provider). To mitigate this concern, the focus will be to adapt the UC apps and provide options to use or not use the additional hardware. UC partners and WP2-4 will investigate what the minimum setup is to run the experience and to what extent they can open the SDKs for different options of hardware use, and WP6 will investigate what potential thresholds there are in terms of costs of hardware for institutions and companies interested in having access to the project products.

It was also discussed to include tutorials at the beginning of the experiences, so users can learn how to navigate in the experience and how to use the different hardware components. Included here is also the option for extra support to users who may not be that experienced with VR, either through support functions available by default throughout the experience or as a mode setting that the user can then set up themselves when starting the experience. To reduce the risk of cybersickness, UC partners will look into options to introduce less artificial movements, but also to further ensure that information about the risk of experiencing cybersickness is communicated to users.

Initially, end users had mentioned that it's important to ensure equal ethnic avatar representations, and here the consortium agreed adding that we should work towards integrating a diverse set of avatar representations that also includes ethnicity, gender, body types, etc. For language barriers, a solution would be to use LLMs to translate or simplify language so that everyone more easily understands. The discussion moved then to how the virtual agent representations would be able to mimic the translations, and it was noted that it may be difficult to ensure this, but that the languages available within the apps would be predetermined, as well as the script that the virtual agent would base itself on when communicating with users – thus having predefined things may help in virtual agent representations and their ability to mimic speech. The UC partners noted that as of now, there are or will be two language options available within the UC apps, namely the native language of the partner organization (Italian, Dutch, and German respectively) and English.

Privacy & data transparency

Here, the main solutions revolved around ensuring transparent communication about what data is collected, shared, and used. For example, through an informed consent message popping up when starting the experience, as well as providing access to the informed consent and how users can access and deal with their data in a settings menu within the app. At this point, the intention of the UC apps is not to record any sort of data about what the users are doing in the experience, at least not in UC2.1 and 2.2. In the case where user actions are recorded in the experience, there will be options for users to decide how they want their data to be handled (e.g., if they want it deleted or visibility to others). In the case of regulations, this will be further discussed and investigated within the consortium.

Cultural & historical integrity

The main solution here was to include a disclaimer at the beginning of the UC2.2 experience stating whether it is based on real events or fully fictional to be transparent with users. In cases where there are real historical facts being presented, additional sources must be provided/referenced so that users can read further if desired.

Realism and functionality

In terms of realistic representations of consequences, the consortium agreed that it is better to integrate warning messages informing about dangerous consequences or even sounds or haptic feedback signaling to the user that they should not do certain actions. This way, users are still able to learn procedures in a safe manner. The consideration of realistic learning was agreed could be applicable across UCs, as the feedback given was that users missed the ability to freely move around themselves, so here a solution was suggested to ensure movement options alongside controllers/haptic gloves for navigational purposes. Finally, discussions on the integration of the real world into the virtual world revolved mainly around the purpose of the UC apps. Specifically in the case of UC2.1, the purpose is to distract the users from the procedure they're going through. Adding virtual representations of the real world in real-time in the environment is quite complex and takes away from the experience. A solution for those users who want a sense of control of their situation is to provide the option of 'pass through' so they can still see the real world while in the virtual world.

3.5.3. System ethics, trust and privacy strategy

This strategy outlines the ethical and practical steps for involving end users in the testing activities across UCs and the two project demonstrators. The approach presented here ensures that all testing is conducted in an ethically sound manner, aligned with the relevant legal requirements (GDPR), as well as with the necessary approvals and oversight.

WP1 (IMEC) has prepared standard guidelines and support materials to be used when conducting tests and evaluation activities involving end users. Deliverable *D1.1 Human Centred Development Phase 1* outlines in Section 7 (and its Adjuncts' Section 11.6), the general recruitment strategy to be used throughout the project as well as the use of informed consent forms.

Our template for evaluation activities (see Adjuncts' Section 8.14), will function as a more detailed manual for how to conduct evaluation activities, what is important to think about before, during, and after the activity, as well as moderator and interviewer guidelines. The informed consents, surveys, and topic lists are to be adjusted per UC and per test, which WP1 (IMEC) will follow up on in WP5 meetings when new evaluation activities are being discussed and planned. Before each test, IMEC will guide the UC owner or other partners responsible for testing through the manual and all evaluation material to ensure that all activities are conducted in a coherent manner. If needed, IMEC will assist the organizer in conducting the tests on-site.

The data collected through these tests are and should be handled in accordance with deliverable *D7.2 Ethics Framework and Data Management Plan I*, where insights into the ethical standards used within PRESENCE and in the handling of personal data is provided. Furthermore, it is important to consider the additional approvals needed for UC2.1, as the hospitals involved will need to provide formal approval before any user testing at their premises can be done, see the Letter of Intent template used in Adjuncts' Section 8.15. As photos and videos may be made of the test sessions, it is crucial that this material also follow GDPR principles. To ensure this, partners who intend to make such material must sign a Data Protection Agreement (DPA) with IMEC (see Adjuncts' section 8.16).

4. Status of KPIs

In this WP, the following KPIs have been defined, which have been partly reached:

- **KPI 1.1:** Provide **one (1) novel mixed-methods research strategy** with inclusive and diversity oriented recruitment plans, providing human-centred requirements and UC definition of the three pillars (WP1, T1.1, T1.2, D1.1).

  Status: Finished by month 6th of the project (see D1.1).

- **KPI 1.2:** Analyse the three pillars in **usability and UX tests with ≥100 participants**, spanning **two (2)** user groups (developers, end-users) reaching a **SUS score ≥80** (i.e., **excellent usability**) and **TAM score ≥ 5** (i.e., indicating **high perceived usefulness and ease of use**) (WP1, T1.3, D1.3).

  Status: We are on track to reach the target number of 100 participants by the end of the project. So far, we have conducted Usability and UX tests with 45 participants. We haven't reached the required SUS and TAM scores yet, which at this point of the project was anticipated, the final scores will be reported in D1.3.

- **KPI 1.3:** Create **a novel methodology** for evaluating social and co-presence at **four (4)** levels, such as place illusion, plausibility, body ownership and co-presence, analysing the impact of the new technologies and UCs, relying on experimental studies encompassing, at least, **150 participants** (WP1, T1.4, D1.3).

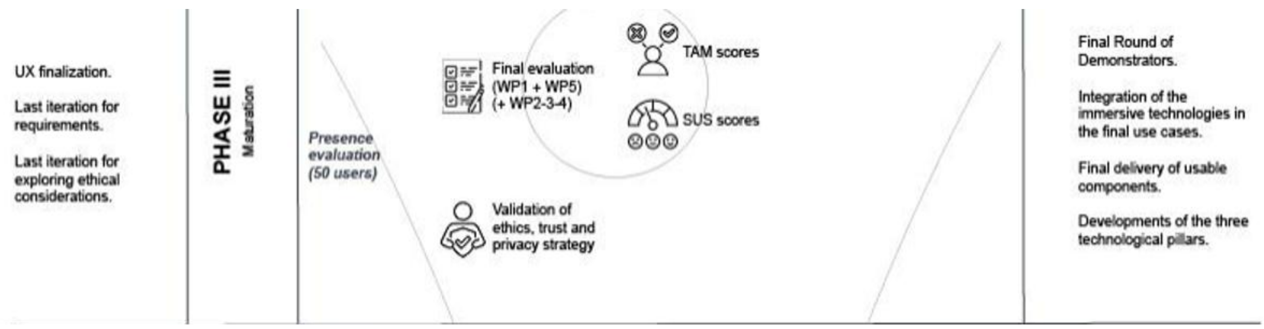
  Status: The number of participants who have evaluated the sense of presence using the Social Presence Questionnaire and/or the IPQ (see Table 13) currently stands at 45. In addition, the presence evaluation studies conducted under T1.4 involved 350 participants. This brings the total number of participants contributing to this KPI to 395.

- **KPI 1.4:** Delivery of the **ethics, trust and privacy strategy** (by M18 in D1.2), describing the use of ethics, privacy and GDPR forms for a safe process involving end-users in the two demonstrators (WP1, WP7 - T1.5, T7.3, D1.2).

  Status: The ethics, trust and privacy strategy has been delivered by M20 in this deliverable D1.2 in Adjuncts' section 8.14.

5. Roadmap Phase III

For the third phase of the project, which runs from month 18 to month 36, an initial roadmap had been developed and visualised in a Miro board[8]. Figure 34 illustrates the iterations between WP1 (Human Centred Development) activities on the left and further development of the PRESENCE technologies and use cases on the right.



[8] For a better view of the timeline, see: https://miro.com/app/board/uXjVKs5vm8M=/?share_link_id=178476633562

Figure 34: Iterative process PRESENCE Phase III

Aligned with WP1 tasks, in phase 3 of the project, the focus will be on gathering feedback during events hosted by the UC partners (Vection, SyncVR, and Zaubar) or through demos at industry fairs. This feedback will primarily be included in WP5 to contribute to achieving KPI 5.3:

"Show higher acceptance and usability rates (≥ 20%) in studies and interviews across at least four (4) different sectors (collaboration, manufacturing, health, cultural heritage) and with ≥300 end users of UCs."

This roadmap was further refined in collaboration with the consortium during the GA in Amsterdam (June 1–3).

Below, the next steps for each task are detailed.

5.1. UC and Requirements Definition & Validation

The initial lists of requirements, drawn up during the first co-creation workshops, will be further refined during the next phase of the project. Starting with the integration of current findings in T1.2 as well as T1.5. Further refinement will be added iteratively, based on new insights gained from testing the PRESENCE applications by users (end-users, professionals and developers). The focus will be on collecting feedback during events organized by the UC partners (Vection, SyncVR, and Zaubar) or through demos at industry fairs.

In the next steps, the consortium partners will review and update the original lists of requirements. New lists have been created per partner, for easier management when reviewing the requirements (for an overview of these lists, consult this document[9]). In these lists, three extra columns have been added to address Dependency, Completion Status %, and Comments. All newly identified requirements will be jointly evaluated to assess their technical feasibility within the scope of the project and to check whether they have already been included in the original lists. If this is not the case, the relevant lists of requirements will be amended accordingly.

5.2. User Centric Approach & UX Testing

While the current technology has not yet achieved the target thresholds of a SUS score above 80 or a TAM score above 5, this was anticipated, as these KPIs were not expected to be met within the first half of the project. To date, Usability- and UX evaluations within WP1 have mainly been conducted for the PRESENCE applications (First Playable app and V.0 PRESENCE app) and the IVA SDK. Usability testing will continue in the next phase to improve these metrics and ensure sufficient participant coverage across all technical pillars.

This task will also serve as a bridge across WPs by assessing the usability of SDKs developed within WP2, WP3, and WP4, as well as the integrated SDK in WP5. The evaluation process will include input from both developers and end-users to ensure comprehensive usability validation. Efforts will be put into fine tuning the current UX surveys as well as alignment across WPs to ensure a streamlined methodology for the Usability and UX evaluations of the technical pillars. This will concretely entail guidelines on which survey questions and metrics to use as well as who and how

[9] Notice to the attention of the EU officers and external reviewers: most of the below URL links direct to the project Repository and thus with access limited to the project consortium members. The documentation is available under demand, contact info@presence-xr.eu

many participants should be included. Having a focused methodology and strategy in place for Usability and UX testing across WPs will ensure comparable outcomes across technical pillars and project applications.

5.3. Trustworthiness and Robustness of AI

The four AI components developed in WP4 have been assessed, both analysing applicable aspects of the AI Act and using the ALTAI questionnaire. In general, it is important to clearly communicate to users when a character has been generated using AI, or users are interacting with a virtual human that uses AI for interaction.

For three of the AI components – generated characters, movements and action recognition – training takes place offline, while interaction with the AI happens in real-time. This means that human control, explainability, etc. are not feasible without disturbing the experience, thus many measures towards trustworthy AI need to focus on managing the training data and process. For the speech and facial interaction component, cloud services are used, thus limiting the control over these components. Some issues, in particular those related to privacy, could be addressed by using modes hosted as part of the PRESENCE deployment, while some risks related to responses of the AI component remain.

The impact of potential risks stemming from the AI components depends on the UC. Apart from revisiting the assessment of components in the second half of the project, we will also focus on assessment of the applications developed in the UCs.

5.4. Presence Evaluation

Virtual museum experiment

The virtual museum experiment serves as a general-purpose abstraction of the PRESENCE UCs, designed to evaluate how XR technologies influence user experience, coordination, and social dynamics in collaborative settings. The technical foundation has been established: a multi-user VE has been developed and optimized for Meta Quest 3 headsets, and basic interaction features and haptic feedback via SenseGlove have been implemented.

The next steps will focus on finalizing the remaining components. This includes the integration of intelligent virtual humans (WP4) into the scenario and the completion of the haptic interaction system (WP3). Once these technologies are fully operational and tested, data collection will begin to evaluate Presence and Co-Presence using both subjective and objective measures, including A3M, task performance, and sentiment analysis.

A follow-up experiment is currently being planned to assess user preferences between different types of avatar representations. The study is in the conceptual phase, with the experimental design under development. In the next phase, we will begin building the scenario and integrating the various avatar types into the environment.

EEG to investigate Co-Presence

This study investigates co-presence in immersive VR through EEG hyperscanning during a silent, cooperative game. Participants interact in a multi-user VE developed in Unity for Meta Quest 3 headsets. Represented by avatars, they sit around a virtual table and jointly play a VR adaptation of

The Mind. EEG is recorded simultaneously from three participants using Biosemi EEG systems, with synchronized acquisition via Lab Streaming Layer. Additional data on heart rate, respiration, gaze, and body orientation are collected to capture engagement and social coordination.

The experiment has been designed (including game design), implemented and piloted. A key technical advance is the development of a custom OpenXR plugin that enables sub-frame-accurate synchronization between visual stimuli and EEG data. This solution allows precise alignment of neural signals with events in the VE, addressing a major challenge in EEG-VR integration.

Two pilot sessions have been completed, and a simpler behavioral version of the task was run to validate the game mechanics and refine participant instructions. The results and participant feedback of this version is guiding improvements in the experimental protocol and questionnaire design.

The next step is to complete analysis of the behavioral data and finalize all materials before launching full-scale EEG data collection. This platform provides a novel way to assess co-presence using both neural and behavioral measures and supports future research on interactive language learning in VR.

5.5. System Ethics, Trust & Privacy

In following up on the implementation of the ethical themes in development, WP1 (IMEC) will follow up with WP5 during their (bi)weekly meetings as well as in preparation of further evaluation activities. WP1 will provide access to the overview of ethical themes and the proposed solutions that came out of the consortium workshop, so that these are known by all consortium partners and can be followed up on by the responsible partner. To further explore and assess ethical considerations of the project technologies, WP1 (IMEC) will also provide a template for evaluation activities (see Adjuncts' Section 8.14), so that other considerations can be flagged and followed up on, but also so that we can successfully compare results across UCs and evaluation phases. By following a standardized template, we also increase our chances of reaching theoretical saturation. Furthermore, WP in collaboration with WP6 will follow up on the implications of the ethical considerations and their solutions for exploitation.

In the next phase of the project, additional tests will be conducted with a more mature version of the UC apps to further explore ethical considerations. Here, we will use a different approach, namely the Guidance Ethics approach (see D1.1, p.26, section 3.2.5 *System Ethics, Trust & Privacy (Overall Methodology*), and they will involve professional users. To conduct these tests, opportunities to collaborate with the business clinics of WP6 will be investigated.

6. Abbreviations and definitions

6.1. Abbreviations

A3M	Adaptive Multi-Modal Matching
AI	Artificial Intelligence
ALTAI	Assessment List of Trustworthy AI

API	Application Programming Interface
AR	Augmented Reality
ATT	Attractiveness
EEG	Electroencephalogram
ERN	Error-related Negativity
ERP	Event-related Potentials
GA	General Assembly
GDPR	General Data Protection Regulation
HCI	Human-Computer Interaction
HMD	Head Mounted Display
HQ-I	Hedonic Quality Relating to Identity
HQ-S	Hedonic Quality concerning Stimulation
IAT	Implicit Association Test
IPQ	Igroup Presence Questionnaire
ISC	Intersubject Correlation
IVA	Intelligent Virtual Agent
IVH	Intelligent Virtual Human
KPI	Key Performance Indicator
LLM	Large Language Model
LSL	Lab-streaming Layer
MR	Mixed Reality
PC	Personal Computer
PI	Place Illusion
PQ	Pragmatic Quality
RL	Reinforcement Learning
SDK	Software Development Kit
SPN	Stimulus-preceding Negativity
SUS	System Usability Scale
TAM2	Extended Technology Acceptance Model

UC	Use Case
UEQ	User Experience Questionnaire
UX	User Experience
VE	Virtual Environment
VR	Virtual Reality
WP	Work Package
XR	Extended Reality

7. References

Ref. 1 Creswell, J. W., & Plano Clark, V. L. (2018). Designing and Conducting Mixed Methods Research (3rd ed.). Sage Publications.

Ref. 2 Griffith, A., & Headley, J. D. (1997). Using a weighted score model as an aid to selecting procurement methods for small building works. *Construction Management & Economics, 15*(4), 341-348.

Ref. 3 Clarke, V., & Braun, V. (2014). Thematic analysis. In *Encyclopedia of critical psychology* (pp. 1947-1952). Springer, New York, NY.

Ref. 4 Mostajeran, F., Li, K., Rings, S., Kruse, L., Wolf, E., Schmidt, S., ... & Steinicke, F. (2025, March). A Toolkit for Creating Intelligent Virtual Humans in Extended Reality. In 2025 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) (pp. 736-741). IEEE.Doi: 10.1109/VRW66409.2025.00149.

Ref. 5 European Parliament & Council. (2024, June 13). Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act). *Official Journal of the European Union*, L 1689, 12 July 2024.

Ref. 6 Radclyffe, C., Ribeiro, M., & Wortham, R. H. (2023). The assessment list for trustworthy artificial intelligence: A review and recommendations. *Frontiers in artificial intelligence*, *6*, 1020592.

Ref. 7 European Commission. (2025, February 6). *Annex to the Communication to the Commission: Approval of the content of the draft communication from the Commission – Commission guidelines on the definition of an artificial intelligence system established by Regulation (EU) 2024/1689 (AI Act) (C(2025) 924 final).*

Ref. 8 Nessler, B., & Wendehorst, C. (2024). *Commission guidelines on the application of the definition of an AI system and the prohibited AI practices established in the AI Act: Response of the European Law Institute* (Publication No. ISBN 978-3-9505495-3-9). European Law Institute.

Ref. 9 Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *3*(2), 130-144.

Ref. 10 Slater, M., Cabriera, C., Senel, G., Banakou, D., Beacco, A., Oliva, R., & Gallego, J. (2023). The sentiment of a virtual rock concert. *Virtual Reality*, *27*(2), 651–675. https://doi.org/10.1007/s10055-022-00685-9

Ref. 11 Talaat, A. S. (2023). Sentiment analysis classification system using hybrid BERT models. *Journal of Big Data*, *10*(1), 110. https://doi.org/10.1186/s40537-023-00781-w

Ref. 12 Alaparthi, S., & Mishra, M. (2021). BERT: A sentiment analysis odyssey. *Journal of Marketing Analytics*, *9*(2), 118–126. https://doi.org/10.1057/s41270-021-00109-8

Ref. 13 Wiesing, M., Fink, G. R., & Weidner, R. (2020). Accuracy and precision of stimulus timing and reaction times with Unreal Engine and SteamVR. *PloS one*, *15*(4), e0231152.

Ref. 14 Küçüktütüncü, E., Macia-Varela, F., Llobera, J., & Slater, M. (2025). The Role of Sensorimotor Contingencies and Eye Scanpath Entropy in Presence in Virtual Reality: a Reinforcement Learning Paradigm. *IEEE Transactions on Visualization and Computer Graphics*.

Ref. 15 Llobera, J., Beacco, A., Oliva, R., Şenel, G., Banakou, D., & Slater, M. (2021). Evaluating participant responses to a virtual reality experience using reinforcement learning. Royal Society open science, 8(9), 210537.

Ref. 16 Wiesing, M., Clocchiatti, A., Ryan, B., Montserrat, R., Soccini, A. M., & Slater, M. (2025). The Elephant in the Room: People Respond with Greater Stress in Mixed Compared to Virtual Reality. Zenodo. https://doi.org/10.5281/zenodo.15196164

Ref. 17 Oliva, R., Wiesing, M., Gállego, J., Inami, M., Interrante, V., Lecuyer, A., McDonnell, R., Nouviale, F., Pan, X., Steinicke, F., & Slater, M. (2025). Where Extended Reality and AI May Take Us: Ethical Issues of Impersonation and AI Fakes in Social Virtual Reality (Version 1). Zenodo. https://doi.org/10.5281/zenodo.15413114.

Ref. 18 Gallego Abellán R, Teruel Piñol C and Slater M (2024) Immersive documentary journalism: exploring the impact of 360° virtual reality compared with a 2D screen display on the responses of people toward undocumented young migrants to Spain. Front. Commun. 9:1474524. doi: 10.3389/fcomm.2024.1474524

Ref. 19 Wiesing, M., Comadran, G., Slater, M. (2025) Confusing virtual reality - An experimental study. 28(6), 112655. https://doi.org/10.1016/j.isci.2025.112655

Ref. 20 https://doi.org/10.34740/kaggle/dsv/9565976

Ref. 21 https://www.kaggle.com/code/melslater/confusion

Ref. 22 https://doi.org/10.34740/kaggle/dsv/9566714

Ref. 23 https://www.kaggle.com/code/melslater/confusion-topic-analysis

Ref. 24 https://doi.org/10.17605/OSF.IO/A3ET6

Ref. 25 Tran, T. Q., Langlotz, T., Young, J., Schubert, T. W., & Regenbrecht, H. (2024). Classifying presence scores: Insights and analysis from two decades of the igroup presence questionnaire (ipq). *ACM Transactions on Computer-Human Interaction*, *31*(5), 1-26.

Ref. 26 Montagut M. et. al., Social VR With Holographic Comms: Enablers for New Engaging Experiences Within the TV / Video Consumption Landscape, IEEE Transactions on Broadcasting, 2025.

8. Adjuncts

8.1. Playbook First Playable app testing (workshop format)

Playbook for co-creation

Exploring user experience and ethical dilemmas with PRESENCE first playable app

Narrative/goal of activity

The main point of this task is to identify gender, ethical, trust and privacy related issues to guide the creation of PRESENCE technologies. At this stage of the development, we want to already try to find ethical issues and user requirements that can help guide the further development of the project technologies.

This particular activity is merged with T1.2 on gathering user requirements, thus we want to gather feedback from the participants on their opinions of the technology and what they think can be improved, etc. T1.5 in itself on identifying ethical issues also serves to gather user requirements, as the participants share their thoughts on potential areas of improvements but also shares their thoughts on what is important to them when it comes to these technologies.

The goal of this activity is to explore potential ethical considerations and opportunities of the PRESENCE first playable app, guiding/aiding the further development of the project products. This will be done by having end users test the first playable app and give their feedback and thoughts in a workshop.

Expected achievements/results:

- With these workshops we want to gather first feedback on the first playable app;
- We want to gather input from participants on ethical considerations, opportunities for inclusivity, and user experience;
- We want to gather user requirements for improving the experience;
- As well as gather input on potential solutions to improve the ethical considerations found.

Practicalities

Forming groups

Each workshop requires 10 participants, and during the workshop these participants will be divided into 3 groups with 3-4 participants in each group. It's important to ensure that the groups are somewhat diverse, 50/50 women and men if possible.

Translating material

Workshops can be held in any language, but it is important that all material, notes, data, transcripts, etc., are translated to English when sent for analysis. This is the responsibility of the organizer of the workshop, and applies also to the translation of slideshow presentations, material for the participants and moderators, etc.

Roles

Experience facilitators (2 persons)

The experience facilitators main task is to ensure that the testing of the experience runs smoothly.

Experience facilitator #1

Experience facilitator #1 should be present with the participant in the room when they are testing the VR experience. This person tells the participant what will happen in the test and should be able to help the participant enter and calibrate the experience, and they will ask the participant some simple questions during the experience. They will also remind them of the workshop later in the evening that day before the participants leave.

Experience facilitator #2

Experience facilitator #2's main purpose is to bring each participant from the entrance to the right room, have them sign all necessary forms, as well as introducing what the test is about. It is important that this person keeps a close eye on the schedule to ensure that each participant is picked up from the entrance at the right time (since they will be asked to arrive 5min before said time).

Main facilitator (1 person)

The main facilitator should introduce the workshop, its goals and outline. They should also be able to answer practical questions and create a safe space for participants.

Break out group facilitators (3 persons)

The break out group facilitators' main responsibilities are:

- Moderate in-group discussions;
- Make notes of verbal discussions within the groups;
- Must ensure a safe space for participants to express their opinions and share feedback with the group.

Participants (10 persons)

The participants rely on the facilitation and moderation of the main facilitator and the break out group facilitators. The participants should actively participate in the session and discussions, and they must feel comfortable expressing and sharing their opinions as well as feeling comfortable discussing with their group members.

Creating a safe space

It's important in this activity that participants can feel comfortable sharing their opinions and thoughts openly to the group and facilitators. However, not everyone is familiar with VR and may thus not feel comfortable showing that they are not so familiar with it. Therefore, it's important to at the beginning of the experience clearly explain how the app works, how they can navigate through the experience, what they will see and do, etc., this is to be done mainly through the user story. This way, even if the participants have differing levels of experience or familiarity with VR, the participants will have the same level of understanding of the experience itself and thus may feel more comfortable sharing their views and opinions with each other. It's important that the main facilitator makes clear at the beginning of the workshop that there are no wrong answers and that we are very much interested in everyone's opinions and thoughts - and that if anyone has any questions they should not hesitate to ask them. This is also something for the break out group facilitators to also do within the groups to ensure that everyone feels comfortable and at ease.

Short program: First playable app testing

Duration	Activity	Comment
5min	Registration + consent form	**This is not included in the testing timing of 30min!**
5min	Welcome and overview	
5min	Calibration	
15min	Main experience	Explain the context of the environment (user scenario) + user test app
5-10min	UX questionnaire	To be filled in (online/offline)
30min total		

Short program: Workshop

Duration	Activity	Comment
30min	Registration	**This is not included in the workshop timing of 3h!**
15min	Introduction & overview	
30min	Rose-Thorn-Bud	
30min	Group reflection on and exploration of ethical considerations	
40min	Break	Pizza break
30min	Continuation ethical considerations exploration and feature ideation	

10min	Closing remarks & next steps	
3h total		

Elaborated program: First playable app testing

Duration		Activity	Notes	Material	Instructions (facilitation)
		Preparation		1 VR headset + controllers (+ USB chord to plug into computer) Computer + monitor Tablet for questionnaire Tape to outline boundary on the floor Printed material: - Script - Consent form (bring a pen to sign) Paper and pen to make observation notes	**1** Ensure that headset and controllers are charged! → Bring charger and batteries! **2** Ensure that all files to run the experience are downloaded and installed. **3** Outline the boundary of which the user can move within, since this otherwise can impact the experience in the VR environment.
5min		Registration		Participant list Consent form + pen	Have the participant write their signature next to their name on the list. Explain the consent form to the participant and let them sign it.

5min		Welcome and overview		Script	Tell the participant about the goal of the test, give an overview of what will happen during the test (see script for more info)
5min		Calibration			Explain to the user that now they will need to calibrate the experience: → Ensure that the image in VR is sharp for the participant, if it's not you will need to change the eye distance of the headset; → Explain to the user how to recentre by pressing the recentre button (important to do this step as it is the calibration step); → Explain how the hand control functions work.
15min		Main experience		Script	Explain the context of the experience to the user (i.e. the scenario → see script for more info) Encourage the participant to share their thoughts as they go and that they can ask questions throughout the experience. Ask guiding questions while the participant is trying the experience to

					get some first feedback.
5-10min		UX questionnaire		PC to fill out questionnaire	Tell the participant that they will now fill out a questionnaire. Participants don't need to answer following questions: - No questions on social presence (except for health use case) - At the end, there are some questions regarding the participant's job in relation to the use case apps. If this is not applicable, the participant can skip these questions. - No additional feedback questions (at the very end)
		Goodbye			Remember to thank the participant for their participation and remind them of the workshop (and practicalities) later that day.

Elaborated program: Workshop

Duration		Activity	Notes	Material	Instructions (facilitation)
		Preparation	Set up tables, presentation, set up snacks and drinks	List of guiding questions for breakout group facilitators (1 on each table); Miro boards and post-it notes on each table;	Prepare the (3) tables and put all needed material on them before participants arrive. Also make sure to distribute the material that the breakout group facilitators will need.
15-30 min		Registration	Open the venue 30min before the workshop is set to begin. Put drinks and glasses (+napkins) at a table. One breakout group facilitator goes to pick up participants at the downstairs entrance (every 5 min starting 15min before the start of the workshop).	Participant list; Sign-in sheet.	All participants must sign in. 5min before the workshop begins, the main facilitator makes an announcement that we will start soon. → Tell participants to sit down in a seat at one of the tables
25min		Intro &	Main facilitator will	Large screen;	

		overview	lead this part	Slideshow with all necessary information.	
	15min	Welcome and introduction to the project (+ video of technical pillars)		-...-	Welcome the participants; Introduce all facilitators; Give them a short introduction to the project and the use case and show video of technical pillars
	10min	Objective & purpose of session		-...-	Tell the participants what the objective of the session is; Explain outline of the workshop: Before the workshop, the participants have tried out the app; now in this workshop they will give us feedback on their experience. **1** First they will in their groups discuss positive aspects, negative aspects, and opportunities of the app. **2** Group discussion on potential ethical considerations they envision in the app (based on videos of technical pillars)

					4 After the break, the participants will together ideate solutions to the envisioned considerations.
30min	5min	Rose-Thorn-Bud (**based on the app they tested)**			The main facilitator explain the post it color system: → **Rose (red/pink):** positive aspects of / things they liked about the app. → **Thorn (yellow):** negative aspects of / things they disliked about the app. → **Bud (green):** potential opportunities to improve the app.
	10min	Brainstorm **(based on the app they tested)**	Take pictures of post-its on visual before the theme sort and discussion!	Visual(s) of environment + post its in 3 different colors	Ask the groups to write as many points as possible within a 10min time limit.
	15	In-group discussion **(based on the app they tested)**	Breakout group facilitators voice record and make notes of discussion.	Pen + paper for breakout group facilitators to make notes of discussion	Group facilitator need to theme sort (on printed theme sort paper) the post it notes and ask the writer to explain/discuss the post it notes. + take pictures of the theme

					sort paper (and post-its)
30min		Group reflection on and exploration of ethical consideration s (**based on final app → use case scenario and video of technical pillars)**	Break out group facilitators voice record and make notes of the discussions/ answers (can do in a mind map format if wanted)	Pen + paper for breakout group facilitators to make notes of discussion.	Main facilitator explain the procedure of the session: → "Now we want you to also consider the video you saw when answering/thinking about these question" "The breakout group facilitators ask the groups the guiding questions and ask them to discuss in the group." → Break out group facilitators: Explore with the participants which ethical theme they deem most important. **!** Tell the groups that there are no right or wrong answers.
40min		Break	Pizza break! Tell participants a time when they should be back (if they leave the room) before next session starts		Prepare material for the next session

30 min		Continuation ethical consideration s			
		Crazy Eights	Breakout group facilitators voice record and make notes of participant presentation s.	Pen + paper (2 per participant); Pen + paper for breakout group facilitators to make notes of presentations.	**1** Give participants paper with a grid of 8 rectangles **2** Participants are asked to come up with potential solutions for the theme they decided as most important in the previous session. **3** Explain that everyone will have 1min per crazy idea (1 idea per box), they can be written or drawn in each box. (Each participant within their groups should write on their own paper, AND should write down at the back of the paper with the grid, their theme) **4** Start the timer and encourage the group to move onto the next idea as each minute passes. **5** At the end of 8min, ask each group to talk through their ideas and come up with their top 3 ideas (ideas that they believe are most

					feasible to implement) to present in the next step. (5 min) **6** After the internal group discussion, one participant per group is asked to present their final ideas to the whole group. → At the same time, one of the breakout group facilitators will write these top 3 ideas per group in a T-bar format. (**in Miro board)** → https://miro.com/app/board/uXjVLjMBg78=/ (15 min)
10min		Closing remarks & next steps	The main facilitator leads here.		
	5min	Summary of key insights			Recap the major ethical themes, user requirements, and areas needing improvement based on the day's discussions.
	5min	Next steps		Sign-out form; Incentive per participant to be given.	Mention how the feedback will be used to improve the VR environment and tell participants about the sign-out

					form where they can indicate whether they would like to get our newsletter and/or to participate in further activities. End by thanking the participants for their participation, stress that we really appreciate their time and effort, and that if they have any questions etc they can reach out*. Give each participant their incentive. *At the end of the slideshow the contact details to the main facilitator should be available.

Materials overview

General:

- Participant list;
- Sign in and out sheet;
- Consent forms;
- Big screen for slides.

Questionnaire:

- Online (done on PC)

Test session of first playable app:

- Pen and paper for experience facilitators (participants can also use pens to sign forms etc)
- VR headsets and controllers (1 set per app test session);
- Monitor/computer per app test session (available via LO dep)

Group discussions:

- Miro boards (A3 printed)
    - Rose-Bud-Thorn exercise: 1 per group for theme sorting (3 total)
    - Theme sort: 1 per group (3 total)
    - Ethical considerations: mind map (1 per group = 3 total)
    - T-bar: 1 total
- Post-its
    - Rose-Bud-Thorn exercise: post-its in 3 different colors (red, yellow, green) per table
    - Ethical considerations exercise(s): post-its per table (color doesn't matter)

Access to material:

- Sign in forms
- Consent form
- Slides
- Miro board (rose-bud-thorn)
- Miro board (mind map)
- Miro board (theme sort)
- Miro board (t-bar)
- Guiding questions
- Manuscript testing sessions

Recruitment of participants

For each workshop we need 10 participants. It is important to ensure a gender balance in recruitment and group division. **Please see this document for all info regarding recruitment efforts:** Planning Master Document**.**

Target groups:

- UC 1.1 and UC1.2: engineering students at the VUB
- UC 2.1: medical students at VUB and other (e.g. regular students from any program at the VUB)
- UC 2.2: Tourism students 7th year secondary school (check which?) and other (e.g. regular students from any program at the VUB)

Setting up the room

General for all sessions:

- There has to be 3 tables with 4-5 chairs (enough chairs for participants + 1 chair for breakout group facilitator) → Important to ensure enough space between the tables so groups are not disturbing each other.

Making notes

Although we can (hopefully) to a great extent rely on technology to help record discussions from each table, it is always good to have a back-up in case the technology doesn't work well. That is why it will be asked of the breakout group facilitators to make notes of group discussions.

Here are some key things to think about:

- Try to make as extensive notes as possible from the verbal discussions of the groups! The more data we can gather, the better.
- How you choose to make notes is very individual, some prefer to make digital notes and others prefer to make handwritten notes - in the case of the latter: please try to write as clearly as possible so that it is readable during the analysis.
- After each workshop, notes will be put in word documents on the Sharepoint - but if there are handwritten notes these should be photographed and put on the Sharepoint as well.

Delivering results

All gathered material and data will be digitized and shared with IMEC for analysis. The notes of the participants and the miro boards need to be photographed and sent to IMEC!

If the workshop is conducted in any other language than English, all data (material, transcripts, etc) must be translated to English before sent to IMEC for analysis (the data and material in the original language must also be included, but will not be analyzed).

All recordings need to be transcribed, this can easily be done through Scribewave. The recordings and transcripts must be uploaded to the SMIT sharepoint folder.

The material is to be uploaded on the SMIT sharepoint project-folder.

Guiding questions (for experience facilitator(s) and breakout group facilitators)

Below you can find the questions that are to be asked by the experience facilitator #1 during the experience as well as the questions to be asked by the breakout group facilitators during the workshop.

Guiding questions during experience

Timing	Question	Follow-up question(s)
Beginning	1. Do you feel comfortable (in the experience)?	**1.1** How does the headset and controllers feel? - Do they need adjusting? **1.2** How do you feel moving around in the environment?

During	2. What do you think about the way of interacting in and with the experience?	**2.1** E.g. controllers, navigation, with other users **2.2** What do you think about the audio? - E.g. easy or not to hear other users / elements of experience (e.g., CH UC)
Ending	3. What are some first impressions of the experience?	**3.1** Is there anything you like or dislike in particular? - E.g. visual quality, functions, etc.

Guiding questions during workshop

Rose-Thorn-Bud* (Based on the app they tested)

**These questions will also be displayed in the slideshow*

Timing	Question	Follow-up question(s)
Beginning	Rose: What aspects of the experience did you like the most or find most interesting? Thorn: What aspects of the experience did you not like or find less interesting? Bud: What opportunities are there to improve the experience?	

Ethical considerations exploration and feature ideation* (Based on final app → use case scenario and technical pillars video)

**These questions will also be displayed in the slideshow*

Theme	Question	Follow-up question(s)
Accessibility	1. What types of people or groups do you think might find this experience easy or enjoyable to use? 2. What types of people or groups do you think might struggle with it or feel left out?	
Privacy and trust	3. If this experience would be collecting the data of the different user roles in this scenario, what kind of information do you think the experience would be collecting about them?	3. What kind of information do you think the experience would be collecting about each user (end user and professional) in different locations? **(For cultural heritage use case: tour guide; what if it would be a holoported expert?)** - E.g. for UC2.2 a memorial site vs at home.
Fairness, respect and inclusiveness	4. What could be some barriers - physical, technical, or cultural - that could prevent someone from fully enjoying or using this experience? 5. What could be an example of something in this experience that might feel unfair or exclusive?	4. E.g., the different personas of the use case 5. E.g., are there any elements of the experience that favor certain groups or that create friction/discomfort for certain people/groups?

8.2. Playbook First Playable app testing (interview format)

1st playable app testing + interviews April 2025

Duration	Activity	Comment
5min	Registration + consent form	**This is not included in timing of 1h**
2min	Welcome and overview	Shortly explain the context of the user test app + controls
5-10min	Main experience	OK to keep it short.
5-10min	Initial impressions of app	Ask questions about what the participant liked/disliked about the app and what improvements can be made. → *See below for questions!*
5-10min	UX questionnaire	To be filled in (online) - Iris printed a QR code so they can do this on their phone **Questions related to job and open questions @ end not needed to be answered**
10min	Video of technical pillars (8min)	After video, explain the context of the environment (user scenario)
20-30min	Interview (ethical considerations)	*See questions below*
30min total		

Initial impressions of the app

1	Rose: What aspects of the experience did you like the most or find most interesting?
2	Thorn: What aspects of the experience did you not like or find less interesting?
3	Bud: What opportunities are there to improve the experience?

Interview (ethical considerations)

Theme	Question	Follow-up question(s)
Accessibility	1. What types of people or groups do you think might find this experience easy or enjoyable to use? 2. What types of people or groups do you think might struggle with it or feel left out?	
Privacy and trust	3. If this experience would be collecting the data of the different user roles in this scenario, what kind of information do you think the experience would be collecting about them?	What kind of information do you think the experience would be collecting about each user (end user and professional) in different locations? **(For cultural heritage use case: tour guide; what if it would be a holoported expert?**)
Fairness, respect and inclusiveness	4. What could be some barriers - physical, technical, or cultural - that could prevent someone from fully enjoying or using this experience? 5. What could be an example of something in this experience that might feel unfair or exclusive?	E.g., the different personas of the use case E.g., are there any elements of the experience that favor certain groups or that create friction/discomfort for certain people/groups?

Add final two questions:

- Which of these ethical themes do you personally consider the most important?
- Can you think of a few (3) possible solutions (ideas) to address this ethical issue

8.3. V.0 PRESENCE app Playbook

Topic list/playbook user testing May 2025

Exploring user experience and social presence with V.0. PRESENCE app

Narrative/goal of activity

The main point of this activity is to explore how the user experience and social presence has improved when integrating the 3 technical pillars of the project (haptics, holoportation, IVH). From these sessions we want to gather user input to help guide the further development of the project technologies. This will be done by having end users test the V.0 PRESENCE app with the integrated technical pillars and give their feedback and thoughts in a semi-structured interview.

Expected achievements/results:

- With these sessions we aim to gather additional feedback on the V.0 PRESENCE app with the integrated technologies;
- We want to gather input from participants on user experience and social presence;
- We want to gather user requirements for improving the experience.

Practicalities

Participant profile and recruitment

For these sessions we aim to invite around 40-60 participants in total, about 10-15 participants per UC. We will aim our recruitment efforts towards students and personnel at the VUB, but also the general public. It is important to ensure the diversity of participants (e.g., gender balance, educational/professional background, technical background, etc).

Translating material

Interviews can be held in any language, but it is important that all material, notes, data, transcripts, etc., are translated to English when sent for analysis. This is the responsibility of the interviewer/test organizer.

Roles

Experience facilitators (3 persons)

The experience facilitators main task is to ensure that the testing of the experience runs smoothly.

Experience facilitator #1

Experience facilitator #1 should be present with the participant in the room when they are testing the VR experience. This person tells the participant what will happen in the test and should be able to help the participant enter and calibrate the experience. This person should also conduct the interview with the participant after the experience has concluded.

Experience facilitator #2

Experience facilitator #2’s have the same task description as experience facilitator #1, during the multi-user tests.

Experience facilitator #3

Experience facilitator #3’s main purpose is to bring each participant from the entrance to the right room, have them sign all necessary forms, as well as introducing what the test is about. It is important that this person keeps a close eye on the schedule to ensure that each participant is picked up from the entrance at the right time (since they will be asked to arrive 5min before said time).

Creating a safe space

It's important in this activity that participants can feel comfortable sharing their opinions and thoughts openly with the interviewer. Not everyone is equally comfortable or experienced with VR technology or the technical pillars of the project, and thus it's crucial that the facilitator clearly explains how the technology and applications work, how they can navigate through the experience, what they will see and do, etc. This can help the participant feel more comfortable in the experience, but also build trust with the facilitator. It's important that the facilitators 1 and 2 make clear at the beginning of the experience and interview that the participant is there to test the experience, not that they are being tested, and that there are no wrong answers.

Short program: V.0 PRESENCE app testing

Duration	Activity	Comment
5min	Registration + consent form	**This is not included in the testing timing of 30min!**
5min	Welcome and overview	
5-10min	Calibration	
15min	Main experience	Explain the context of the environment (user scenario) + user will test the app
5-10min	UX questionnaire	To be filled in (online/offline)
30min total		

Short program: Interview

Duration	Activity	Comment
5min	First impressions	
25min	Reflection on social presence and UX	
30min total		

Elaborated program: V.0 PRESENCE app testing

Duration		Activity	Notes	Material	Instructions (facilitation)
		Preparation	In mutli-user contexts, 2 separate rooms are needed!	1 VR headset + controllers (+ USB chord to plug into computer) Computer + monitor QR code for UHAM questionnaire (the participant can also fill it out on the facilitators computer) Tape to outline boundary on the floor Printed material: - Script - Consent form (bring a pen to sign) Device to record sound (mobile phone is sufficient)	**1** Ensure that headset and controllers are charged! → <u>Bring charger and batteries!</u> **2** Ensure that all files to run the experience are downloaded and installed. **3** Outline the boundary of which the user can move within, since this otherwise can impact the experience in the VR environment.
5min		Registration		Participant list Consent form + pen	Have the participant write their signature next to their name on the list. Explain the consent form to the participant and let them sign it.
5min		Welcome and overview		Script	Tell the participant about the goal of the test, give an overview of what will happen during the test (see

					script for more info)
5min		Calibration			Explain to the user that now they will need to calibrate the experience: → Ensure that the image in VR is sharp for the participant, if it's not you will need to change the eye distance of the headset; → Explain to the user how to recentre by pressing the recentre button (important to do this step as it is the calibration step); → Explain how the hand control functions work. Help the participant put on other necessary equipment and explain how it works (e.g., vest, haptic glove, etc)
15min		Main experience		Script	Explain the context of the experience to the user (i.e. the UC scenario) Encourage the participant to share their thoughts as they go and that they can ask questions throughout the experience.
5-10min		UX questionnaire		PC to fill out questionnaire	Tell the participant that they will now fill out a questionnaire. Participants don't need to answer following questions: - At the end, there are some questions

					regarding the participant's job in relation to the use case apps. If this is not applicable, the participant can skip these questions.

Elaborated program: Interview

Duration	Activity	Question	Follow-up
5min	First impressions	What are your first impressions of the app/experience?	Was there anything in particular that you liked/disliked? - e.g., design, technology, etc.
		What stood out to you about this experience?	E.g., anything within the environment, or how you felt when entering the experience?
25min	Reflection UX and social presence	What was your impression regarding navigating the experience?	E.g., controllers, navigation… Was there anything that felt confusing or difficult about this? (if so, what?)
		How did you feel about interacting with the IVA?	Could you explain what it was that made you evaluate it this way?
		How did the behavior of the IVA in the environment affect your sense of immersion?	
		How did you feel about interacting with the basic avatar?	Could you explain what it was that made you evaluate it this way?

		How did you feel about interacting with the holoported person in the experience?	Could you explain what it was that made you evaluate it this way? What aspects made it feel more / less natural?
		How did you feel about the haptic feedback you received from the **glove** when interacting with objects in the environment? +[...] haptic feedback from the **vest** [...]?	Could you explain what it was that made you evaluate it this way? Could you explain what it was that made you evaluate it this way?
		Can you describe how aware you were of the other person during the experience?	How do you feel the haptics contributed to this? How do you feel the holoported representation of the other person contributed to this? How do you feel the IVA contributed to this?
		Were there any specific nonverbal cues that made someone feel more 'there' with you?	E.g., gestures, body language…
		What do you think can be improved to make you feel more immersed and present in the experience?	I.e., holoportation, haptics, IVA
Have the participant sign the sign-out sheet!			

Materials overview

General:

- Participant list;
- Sign in and out sheet;
- Consent forms.

Questionnaire:

- Online (done on participants' phones or organizer's computer)
- Printed QR code to access questionnaire

Test session of V.0 PRESENCE app:

- Pen and paper for experience facilitators (participants can also use pens to sign forms etc)
- VR headsets and controllers (2 sets per app test session);
- glove and haptic vest
- cameras for holoportation
- Monitor/computers per app test session;
- Tech needed for TPs.

Interview:

- Semi-structured interview question list (see above)

Access to material:

- Sign in + out forms
- Consent form
- Manuscript testing sessions

Recruitment of participants

For each session we need 10-15 participants. It is important to ensure a gender balance in recruitment and group division. **Please see this document for all info regarding recruitment efforts:** Master Planning Document.

Setting up the room

General for all sessions:

- Important to ensure that there are 2 rooms available for each session in multi-user contexts, as otherwise participants will disturb each other when doing the test and interview!
- There has to be enough space for the participant to move around in the room when in the VR experience, and space for the facilitator to monitor the experience on their computer.
- There also need to be room to set up the holoportation cameras + space for the participant to move around.

Making notes

Although we will be voice recording the sessions to capture what the participant says, it's also useful to have observation notes from each session to capture what the participant does and how participants address and interact with each other.

Here are some key things to think about:

- If possible, try to make some observation notes during the experience, especially of behavior of the participants and whether there are some things that are difficult/frustrating/going well etc for them.
- How you choose to make notes is very individual, some prefer to make digital notes and others prefer to make handwritten notes - in the case of the latter: please try to write as clearly as possible so that it is readable during the analysis.
- After each session, notes will be put in word documents on the Sharepoint - but if there are handwritten notes these should be photographed and put on the Sharepoint as well.

Delivering results

All gathered material and data (interview recordings, translated transcripts, translated observation notes (if applicable)) will be digitized and shared with IMEC for analysis.

If the interview is conducted in any other language than English, all data (material, transcripts, etc) must be translated to English before sent to IMEC for analysis (the data and material in the original language must also be included, but will not be analyzed).

All recordings need to be transcribed, this can easily be done through services like e.g., Scribewave. The recordings and transcripts must be uploaded to the IMEC-SMIT Sharepoint.

Data handling: IMPORTANT

IMEC will only handle and have access to data such as interview recordings, translated transcripts, translated observation notes (if applicable), and informed consent forms. All other data is under the responsibility of the organizer, e.g., sign-in and out forms, emails, names (and pseudonymization key), videos/photos, etc.

Since you will be storing this other data, you need to do it in a safe manner. In IMEC we use SharePoint, so we recommend to use that platform as well, unless you have another option (disclaimer: we don't recommend using Google Drive for storing this type of data, as it's not that safe).

8.4. IVH SDK Survey (UX evaluation and presence evaluation)

Section A: Consent

Please read this page carefully before deciding whether you want to participate in this survey.

Your participation in this survey will provide insight into the usability and user experience of our developed SDKs. The evaluation of the data collected in the context of this survey may be published in scientific journals, conferences, the PRESENCE website, or passed on to other persons in anonymized form.

Your participation in this survey should not induce risks or harm. Your participation is voluntary and you can withdraw from the survey at any time without giving reasons and without consequences. If you withdraw from the survey, all data related to your participation will be destroyed.

The collection and analysis of the survey data is pseudonymized. Only the data necessary for the proper conduct of the project will be collected, i.e.: demographic information and your answers to the questionnaires. To be able to allocate your data correctly without violating confidentiality, we need a code or codeword (i.e., ID). The ID is constructed in such a way that nobody, including us, can trace it back to you. However, you can reconstruct your codeword at any time if you are asked for it and have forgotten it. You only need to know the rule by which you have to construct the ID.

All information collected as part of the survey will be treated confidentially within the limits set by law. The General Data Protection Regulation (GDPR) applies to the processing of personal data. You can access your data, request rectification, correction, deletion, or revoke consent, by writing to Dr. Fariba Mostajeran (E-Mail: fariba.mostajeran.gourtani@uni-hamburg.de) or Prof. Dr. Frank Steinicke (E-Mail: frank.steinicke@uni-hamburg.de). It will be necessary to provide us with the ID that you generated to participate in this survey and attach a valid identification document that identifies you.

A1. **I hereby confirm that I have read and understood the information on participation. I understand the nature and purpose of my participation in this survey. I am voluntarily participating in this survey.**

Agree ☐

Section B: Demographic

B1.

B2. **What is your age?**

B3. Which gender do you feel you belong to?

- Female ☐
- Male ☐
- Non-Binary ☐
- Prefer not to answer ☐
- Other ☐

Other

[ ]

B4. Please enter your location (e.g. Hamburg).

[ ]

B5. What organization do you use the SDK in (e.g. University of Hamburg)?

[ ]

B6. How much prior experience did you have with Unity development before using the SDK?

I have never used Unity before ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ I am a Unity expert

B7. How much prior experience did you have with XR (including VR, AR, and MR) before using the SDK?

I have never used VR before ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ I am a VR expert

B8. Which PRESENCE SDK did you use?

- Intelligent Virtual Human SDK ☐
- Digital Touch SDK ☐
- Holoconferencing SDK ☐

B9. How much prior experience did you have with virtual agents/avatars before using the SDK?

No Experience ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ I am an expert

B10. How much prior experience did you have with digital touch/haptics before using the SDK?

No Experience ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ I am an expert

B11. How much prior experience did you have with holoportation before using the SDK?

No Experience ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ I am an expert

Section C: System Usability Scale

C1. Please rate how much you agree/disagree with each statement.

	Strongly disagree				Strongly agree
I think that I would like to use this system frequently	☐	☐	☐	☐	☐
I found the system unnecessarily complex	☐	☐	☐	☐	☐
I thought the system was easy to use	☐	☐	☐	☐	☐
I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐
I found the various functions in this system were well integrated	☐	☐	☐	☐	☐
I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐
I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐
I found the system very cumbersome to use	☐	☐	☐	☐	☐
I felt very confident using the system	☐	☐	☐	☐	☐
I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐

Section D: AttrackDiff

D1. With the help of the word pairs, please enter what you consider the most appropriate description for the SDK.

human I technical	☐	☐	☐	☐	☐	☐	☐
isolating I connective	☐	☐	☐	☐	☐	☐	☐
pleasant I unpleasant	☐	☐	☐	☐	☐	☐	☐
inventive I conventional	☐	☐	☐	☐	☐	☐	☐
simple I comlicated	☐	☐	☐	☐	☐	☐	☐
professional I unprofessional	☐	☐	☐	☐	☐	☐	☐
ugly I attractive	☐	☐	☐	☐	☐	☐	☐
practical I impractical	☐	☐	☐	☐	☐	☐	☐
likeableI disagreeable	☐	☐	☐	☐	☐	☐	☐
cumbersome I straightforward	☐	☐	☐	☐	☐	☐	☐

Section E: AttrackDiff

E1. With the help of the word pairs, please enter what you consider the most appropriate description for the SDK.

stylish I tacky	☐	☐	☐	☐	☐	☐	☐
predictable I unpredictable	☐	☐	☐	☐	☐	☐	☐
cheap I premium	☐	☐	☐	☐	☐	☐	☐
alienating I integrating	☐	☐	☐	☐	☐	☐	☐
brings me closer to people I seperates me from people	☐	☐	☐	☐	☐	☐	☐
unpresentable I presentable	☐	☐	☐	☐	☐	☐	☐
rejecting I inviting	☐	☐	☐	☐	☐	☐	☐
unimaginative I creative	☐	☐	☐	☐	☐	☐	☐

good I bad	☐	☐	☐	☐	☐	☐	☐

Section F: AttrackDiff

F1. With the help of the word pairs, please enter what you consider the most appropriate description for the SDK.

confusing I clearly structured	☐	☐	☐	☐	☐	☐	☐
repelling I appealing	☐	☐	☐	☐	☐	☐	☐
bold I cautious	☐	☐	☐	☐	☐	☐	☐
innovative I conservative	☐	☐	☐	☐	☐	☐	☐
dull I captivating	☐	☐	☐	☐	☐	☐	☐
undemanding I challenging	☐	☐	☐	☐	☐	☐	☐
motivating I discouraging	☐	☐	☐	☐	☐	☐	☐
novel I ordinary	☐	☐	☐	☐	☐	☐	☐
unruly I manageable	☐	☐	☐	☐	☐	☐	☐

Section G: TAM2

G1. Please rate how much you agree/disagree with each statement.

	strongly disagree	moderately disagree	somewhat disagree	neutral	somewhat agree	moderately agree	strongly agree
Assuming I have access to the system, I intend to use it.	☐	☐	☐	☐	☐	☐	☐
Given that I have access to the system, I predict that I would use it.	☐	☐	☐	☐	☐	☐	☐
Using the system improves my performance in my project/job.	☐	☐	☐	☐	☐	☐	☐
Using the system in my project/job increases my productivity.	☐	☐	☐	☐	☐	☐	☐
Using the system enhances my effectiveness in my project/job.	☐	☐	☐	☐	☐	☐	☐
I find the system to be useful in my project/job.	☐	☐	☐	☐	☐	☐	☐
My interaction with the system is clear and understandable.	☐	☐	☐	☐	☐	☐	☐

	strongly disagree	moderately disagree	somewhat disagree	neutral	somewhat agree	moderately agree	strongly agree
Interacting with the system does not require a lot of my mental effort.	☐	☐	☐	☐	☐	☐	☐
I find the system to be easy to use.	☐	☐	☐	☐	☐	☐	☐
I find it easy to get the system to do what I want it to do.	☐	☐	☐	☐	☐	☐	☐

Section H: Additional Feeback (optional)

H1. Can you describe your experience working with the SDK?

H2. Which parts of the SDK did you like? Which part did you not like?

H3. What sort of problem did you have to face when working with the SDK?

H4. What would you like to see added to the SDK?

H5. **What would you like to removed/changed from the SDK?**

H6. **Would you work with the SDK again?**

H7. **Would you recommend the SDK to others?**

H8. **Do you have additional Feedback on the SDK?**

8.5. Application Survey (UX evaluation and presence evaluation)

Section A: Consent

Please read this page carefully before deciding whether you want to participate in this survey.

Your participation in this survey will provide insight into user experience of our developed application(s). The evaluation of the data collected in the context of this survey may be published in scientific journals, conferences, the PRESENCE website, or passed on to other persons in anonymized form.

Your participation in this survey should not induce risks or harm. Your participation is voluntary and you can withdraw from the survey at any time without giving reasons and without consequences. If you withdraw from the survey, all data related to your participation will be destroyed.

The collection and analysis of the survey data is pseudonymized. Only the data necessary for the proper conduct of the project will be collected, i.e.: demographic information and your answers to the questionnaires. To be able to allocate your data correctly without violating confidentiality, we need a code or codeword (i.e., ID). The ID is constructed in such a way that nobody, including us, can trace it back to you. However, you can reconstruct your codeword at any time if you are asked for it and have forgotten it. You only need to know the rule by which you have to construct the ID.

All information collected as part of the survey will be treated confidentially within the limits set by law. The General Data Protection Regulation (GDPR) applies to the processing of personal data. You can access your data, request rectification, correction, deletion, or revoke consent, by writing to Dr. Fariba Mostajeran (E-Mail: fariba.mostajeran.gourtani@uni-hamburg.de) or Prof. Dr. Frank Steinicke (E-Mail: frank.steinicke@uni-hamburg.de). It will be necessary to provide us with the ID that you generated to participate in this survey and attach a valid identification document that identifies you.

A1. **I hereby confirm that I have read and understood the information on participation. I understand the nature and purpose of my participation in this survey. I am voluntarily participating in this survey.**

Agree ☐

Section B: Demographic

B1.

B2. **What is your age?**

B3. Which gender do you feel you belong to?

- Female ☐
- Male ☐
- Non-Binary ☐
- Prefer not to answer ☐
- Other ☐

Other

B4. Please enter your location (e.g. Hamburg).

B5. How much experience do you have with XR (including VR, AR and MR)?

I have never used Unity before ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ I am a Unity expert

B6. Which PRESENCE application did you use?

- Intelligent Virtual Human ☐
- Digital Touch ☐
- Holoconferencing ☐
- Professional Collaboration Use Case ☐
- Manufacturing Training Use Case ☐
- Health Use Case ☐
- Cultural Heritage Use Case ☐

Section C: System Usability Scale

C1. Please rate how much you agree/disagree with each statement.

	Strongly disagree				Strongly agree
I think that I would like to use this system frequently	☐	☐	☐	☐	☐

	Strongly disagree				Strongly agree
I found the system unnecessarily complex					
I thought the system was easy to use					
I think that I would need the support of a technical person to be able to use this system					
I found the various functions in this system were well integrated					
I thought there was too much inconsistency in this system					
I would imagine that most people would learn to use this system very quickly					
I found the system very cumbersome to use					
I felt very confident using the system					
I needed to learn a lot of things before I could get going with this system					

Section D: AttrackDiff

D1. With the help of the word pairs, please enter what you consider the most appropriate description for the application.

human I technical							
isolating I connective							
pleasant I unpleasant							
inventive I conventional							
simple I comlicated							
professional I unprofessional							
ugly I attractive							
practical I impractical							
likeablel disagreeable							
cumbersome I straightforward							

Section E: AttrackDiff

E1. With the help of the word pairs, please enter what you consider the most appropriate description for the application.

Word pair							
stylish I tacky	☐	☐	☐	☐	☐	☐	☐
predictable I unpredictable	☐	☐	☐	☐	☐	☐	☐
cheap I premium	☐	☐	☐	☐	☐	☐	☐
alienating I integrating	☐	☐	☐	☐	☐	☐	☐
brings me closer to people I seperates me from people	☐	☐	☐	☐	☐	☐	☐
unpresentable I presentable	☐	☐	☐	☐	☐	☐	☐
rejecting I inviting	☐	☐	☐	☐	☐	☐	☐
unimaginative I creative	☐	☐	☐	☐	☐	☐	☐
good I bad	☐	☐	☐	☐	☐	☐	☐

Section F: AttrackDiff

F1. With the help of the word pairs, please enter what you consider the most appropriate description for the application.

Word pair							
confusing I clearly structured	☐	☐	☐	☐	☐	☐	☐
repelling I appealing	☐	☐	☐	☐	☐	☐	☐
bold I cautious	☐	☐	☐	☐	☐	☐	☐
innovative I conservative	☐	☐	☐	☐	☐	☐	☐
dull I captivating	☐	☐	☐	☐	☐	☐	☐
undemanding I challenging	☐	☐	☐	☐	☐	☐	☐
motivating I discouraging	☐	☐	☐	☐	☐	☐	☐
novel I ordinary	☐	☐	☐	☐	☐	☐	☐
unruly I manageable	☐	☐	☐	☐	☐	☐	☐

Section G: IPQ

Please evaluate the following statements.

G1. In the computer generated world I had a sense of "being there"

not at all | very much: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G2. Somehow I felt that the virtual world surrounded me.

fully disagree | fully agree: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G3. I felt like I was just perceiving pictures.

fully disagree | fully agree: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G4. I did not feel present in the virtual space.

did not feel present | felt present: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G5. I had a sense of acting in the virtual space, rather than operating something from outside.

fully disagree | fully agree: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G6. I felt present in the virtual space.

fully disagree | fully agree: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G7. How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

extremely aware | not aware at all: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G8. I was not aware of my real environment.

fully disagree | fully agree: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

G9. I still paid attention to the real environment.

	0	1	2	3	4	5	6
fully disagree | fully agree	☐	☐	☐	☐	☐	☐	☐

G10. I was completely captivated by the virtual world.

	0	1	2	3	4	5	6
fully disagree | fully agree	☐	☐	☐	☐	☐	☐	☐

G11. How real did the virtual world seem to you?

	0	1	2	3	4	5	6
completely real | not real at all	☐	☐	☐	☐	☐	☐	☐

G12. How much did your experience in the virtual environment seem consistent with your real world experience ?

	0	1	2	3	4	5	6
not consistent | very consistent	☐	☐	☐	☐	☐	☐	☐

G13. How real did the virtual world seem to you?

	0	1	2	3	4	5	6
about as real as an imagined world | indistinguishable from the real world	☐	☐	☐	☐	☐	☐	☐

G14. The virtual world seemed more realistic than the real world.

	0	1	2	3	4	5	6
fully disagree | fully agree	☐	☐	☐	☐	☐	☐	☐

Section H: Social Presence Questionnaire

If your experience involved virtual humans (such as avatars and agents), please respond to the following items, keeping in mind your interactions with these virtual characters. If you did not have experiences with virtual humans, you may skip this section.

H1. I perceive that I am/was in the presence of another person in the room with me.

	1	2	3	4	5	6	7
fully disagree | fully agree	☐	☐	☐	☐	☐	☐	☐

H2. I feel that the person is/was watching me and is/was aware of my presence.

	1	2	3	4	5	6	7
fully disagree | fully agree	☐	☐	☐	☐	☐	☐	☐

H3. **The thought that the person is/was not a real person crosses my mind often.**

	1	2	3	4	5	6	7
fully disagree I fully agree	☐	☐	☐	☐	☐	☐	☐

H4. **The person appears/appeared to be sentient, conscious, and alive to me.**

	1	2	3	4	5	6	7
fully disagree I fully agree	☐	☐	☐	☐	☐	☐	☐

H5. **I perceive/perceived the person as being only a computerized image, not as a real person.**

	1	2	3	4	5	6	7
fully disagree I fully agree	☐	☐	☐	☐	☐	☐	☐

Section I: TAM2

I1. **Please rate how much you agree/disagree with each statement.**

	strongly disagree	moderately disagree	somewhat disagree	neutral	somewhat agree	moderately agree	strongly agree
Assuming I have access to the system, I intend to use it.	☐	☐	☐	☐	☐	☐	☐
Given that I have access to the system, I predict that I would use it.	☐	☐	☐	☐	☐	☐	☐
Using the system improves my performance in my project/job.	☐	☐	☐	☐	☐	☐	☐
Using the system in my project/job increases my productivity.	☐	☐	☐	☐	☐	☐	☐
Using the system enhances my effectiveness in my project/job.	☐	☐	☐	☐	☐	☐	☐
I find the system to be useful in my project/job.	☐	☐	☐	☐	☐	☐	☐
My interaction with the system is clear and understandable.	☐	☐	☐	☐	☐	☐	☐
Interacting with the system does not require a lot of my mental effort.	☐	☐	☐	☐	☐	☐	☐
I find the system to be easy to use.	☐	☐	☐	☐	☐	☐	☐
I find it easy to get the system to do what I want it to do.	☐	☐	☐	☐	☐	☐	☐

Section J: Additional Feeback (optional)

J1. **Can you describe your experience with the application?**

J2. **Which parts of the application did you like? Which parts did you not like?**

J3. **What sort of problem did you have to face?**

J4. **What would you like to see added?**

J5. **What would you like to removed/changed?**

J6. **Would you use the application again?**

J7. **Would you recommend the application to others?**

J8. **Do you have additional Feedback?**

8.6. Cooperative Experience Survey (for behavioral/eye-tracking version of The Mind experiment)

Please indicate how much you agree with each of the following statements.

Por favor, indica cuánto estás de acuerdo con cada una de las siguientes afirmaciones.

Response Scale / Escala de respuesta (1–7):

1 = Strongly disagree / Totalmente en desacuerdo

2 = Disagree / En desacuerdo

3 = Somewhat disagree / Algo en desacuerdo

4 = Neutral / Neutral

5 = Somewhat agree / Algo de acuerdo

6 = Agree / De acuerdo

7 = Strongly agree / Totalmente de acuerdo

Section A: Experience During This Game / Experiencia Durante Este Juego

1. I felt that everyone contributed meaningfully to our success.
   Sentí que todos contribuyeron significativamente a nuestro éxito.

2. I would have preferred to do the task alone.
   Preferiría haber realizado la tarea solo/a.

3. I felt like we were really working as a team.
   Sentí que realmente estábamos trabajando como un equipo.

4. I was satisfied with how we worked together.
   Estuve satisfecho/a con cómo trabajamos juntos.

5. I felt uncomfortable depending on someone else to succeed.
   Me sentí incómodo/a dependiendo de otra persona para tener éxito.

6. I felt bored while playing the game.
   Me sentí aburrido/a mientras jugaba.

7. I felt like my teammate(s) and I communicated well.
   Sentí que mis compañeros/as y yo nos comunicamos bien.

8. I enjoyed contributing to our team's success.
   Disfruté al contribuir al éxito de nuestro equipo.

9. The task was more engaging because I was cooperating with others.
   La tarea fue más interesante porque estaba cooperando con otras personas.

10. I felt proud of what we accomplished together.
    Me sentí orgulloso/a de lo que logramos juntos.

11. I found the shared victory more enjoyable than winning alone.
    Disfruté más la victoria compartida que si hubiera ganado solo/a.

12. I was annoyed by how my teammate(s) played.
    Me molestó la forma en que mis compañeros/as jugaron.

13. I felt good knowing that we succeeded as a team.
    Me sentí bien sabiendo que tuvimos éxito como equipo.

14. Winning together gave me a warm, satisfying feeling.
    Ganar juntos me dio una sensación cálida y satisfactoria.

15. I felt frustrated during the task.
    Me sentí frustrado/a durante la tarea.

Section B: Your General Tendencies / Tus Tendencias Generales

16. I often feel motivated when others rely on me.
    A menudo me siento motivado/a cuando los demás dependen de mí.

17. I like the feeling of succeeding with others more than succeeding alone.
    Me gusta más la sensación de tener éxito con otros que tener éxito solo/a.

18. I tend to get along well with others during shared tasks.
    Suelo llevarme bien con los demás durante tareas compartidas.

19. I often feel anxious in group activities.
    A menudo me siento ansioso/a en actividades grupales.

20. I usually enjoy working in teams.
    Por lo general, disfruto trabajar en equipo.

8.7. Presence Survey (for behavioral/eye-tracking version of The Mind experiment)

Please rate your sense of being in the virtual environment, on a scale from 1 to 7, where 7 represents your normal experience of being in a place.

1 2 3 4 5 6 7

To what extent were there times during the experience when the virtual environment was the reality for you?

1 2 3 4 5 6 7

When you think back to the experience, do you think of the virtual environment more as images that you saw or more as somewhere that you visited?

1 2 3 4 5 6 7

During the time of the experience, which was the strongest on the whole, your sense of being in the virtual environment or of being elsewhere?

1 2 3 4 5 6 7

Consider your memory of being in the virtual environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today?

1 2 3 4 5 6 7

During the time of your experience, did you often think to yourself that you were actually in the virtual environment?

1 2 3 4 5 6 7

8.8. Elephant in the Room Pre-questionnaire (ENG)

Block 3

Participant Information Sheet

Please read this information carefully and feel free to ask any questions you may have. The researchers will answer all your questions.

The study aims to examine the differences in the emotional experience of stressful stimuli in virtual and augmented reality environments. Virtual Reality (VR) and Augmented Reality (AR) provide unique sensations known as "Presence," which encompasses two illusions: Place Illusion (PI) and Plausibility Illusion (Psi). PI is the illusion of being in the virtual world, while Psi is the illusion that events in the virtual environment are actually happening. With the increasing realism of virtual scenarios, it's essential to understand their psychological impact and potential negative effects, such as trauma or PTSD-like symptoms. This study will help us gain insights into how VR and AR experiences influence emotional and physiological responses.

In this study, you will experience potentially intense stimuli, such as the presence of a virtual animal, in both VR and AR settings. We will measure both psychological and physiological responses to these stimuli to better understand how they are experienced and their impact on users.

The study will take about 40 minutes. Before the experiment, you will answer some questions. During the experiment, you will have to answer some questions and complete an activity that requires the use of virtual reality equipment (Meta Quest 3).

During the experiment, you will wear a head-mounted display, which either will present the real-world environment you are currently in, through cameras attached to the headset, or you will experience a virtual environment. In the experiment, you will see either a rabbit, a dog, or a wolf sitting in front of you. None of the animals will at any point attack or directly threaten you but will remain seated in front of you. At various times, an element of the virtual environment changes (e.g., switch from the real room to the virtual room, or switch between the dog and the wolf). Whether you accept these changes or not is up to you. **Remember that you will be free to leave the experiment at any time without giving explanations.** You can also ask us to delete any records of your responses.

You will be asked to complete several questionnaires before and after the sessions. Additionally, your heart rate will be measured during the experiment. The

measurements are non-invasive and pose no risk to physical integrity. The information collected during the study will be disseminated in such a way that you cannot be individually identified. In all the reports of this work (scientific publications, congresses, etc.) your participation will be discussed as a group and you will not be mentioned as an individual. In case of mentioning any of the comments or any of the responses of you or of other participants, it will always be done completely anonymously.
For your time and any inconvenience caused, you will be compensated with 10 euros.

IMPORTANT When people use a Virtual Reality system, some often experience a certain feeling of nausea. If at any point in the study, you wish to stop due to this or a different reason, please say so and we will stop the experience immediately. Some research suggests that people who use a virtual reality headset may experience some minor visual disturbance soon after. We do not know any long-term studies, but there are studies from the late 1990s that suggest that an after-effect can occur within 30 minutes. Display equipment today is much improved, however. With some types of videos, there is the possibility of generating an epileptic episode, as has been reported to occur in some video games. Immersive Virtual Reality can have lasting psychological and behavioural influences on participants. Since virtual reality has only recently been introduced to the public, some risks may currently be unknown. However, in all the studies conducted under Prof. Mel Slater's research group over the past 3 decades, no adverse effect of technology on psychology or behavior has ever been found.

Notable Findings

The examination is conducted solely for research purposes. A medical or psychological evaluation of your data will not take place. However, we may notice an unusual finding during the examination. In such a case, we will inform you and recommend that you have this result further evaluated by your general practitioner. You can only participate in this study if you agree to be informed about any notable findings. Should a condition be diagnosed during this diagnostic evaluation, you may face potential disadvantages, such as difficulties in obtaining private health insurance or life insurance.

Please read, understand well, and sign your informed consent. Remember that you can leave the study at any time without giving any reason. In case you have any questions or comments related to the study please contact us: Prof. Mel Slater (melslater@ub.edu) .

Thank you for your participation!

Demographics

What is the ID number given to you by the experimenter?

[ ]

What is your gender

- ○ Male
- ○ Female
- ○ Other
- ○ Prefer not to say

What is your age?

[ ]

How much have you experienced Virtual Reality before?

	1. Never	2	3	4. Occasionally	5	6	7. A great amount
I have experienced Virtual Reality	○	○	○	○	○	○	○

What's your level of knowledge of computer programming?

	1. None	2	3	4. Occasional use	5	6	7. Expert
My knowledge of computer programming is:	○	○	○	○	○	○	○

How many times have you played video games in the past year?

	0	1-5	6-10	11-15	16-20	21-25	more than 25
In the past year I have played:	○	○	○	○	○	○	○

How many hours have you played video games in the past week?

	0	1-2	3-4	5-6	7-8	9-10	more than 10
Hours I've played in the past week:	○	○	○	○	○	○	○

Block 4

PARTICIPANT CONSENT FORM

Research project title: From Wolves to Rabbits: Emotional and Physiological Reactions in Augmented and Virtual Environments

Please read and answer the following questions carefully:

	Yes	No
Have you read all the information that has been provided to you about this project?	○	○
Have you had the opportunity to ask and comment on questions about the project?	○	○
Have you received enough information about this project?	○	○
Have you understood that you are free to withdraw from this project without giving reasons and without affecting any other of your rights?	○	○
At any time	○	○
Without giving any reason	○	○
Have you understood the possible risks associated with your participation in this project?	○	○
Do you agree to participate?	○	○
Do you agree that your personal data be processed according to the information provided?	○	○

Block 5

Which researcher informed you about this project? (name and surname(s))

Block 6

I certify that:
- I am of legal age (18 years or older).
- I have not consumed more than two units of alcohol in the last 6 hours (2 units of alcohol = 1 beer or 2 glasses of wine).
- I am not taking any type of psychoactive medication.
- I do not suffer from epilepsy.
- I will not drive cars, motorcycles, or bicycles or use any complex machines that could be dangerous for me or others, during the 3 hours after finishing any Virtual Reality experience in this study.
- I do not suffer from post-traumatic stress disorder or any other type of psychological disorder

Please sign

× SIGN HERE

clear

Powered by Qualtrics

8.9. Elephant in the Room Pre-questionnaire (SP)

Block 3

Hoja de Información para el Participante
Por favor, lea esta información con atención y no dude en hacer cualquier pregunta que tenga. Los investigadores responderán todas sus preguntas.
El estudio tiene como objetivo examinar las diferencias en la experiencia emocional de estímulos estresantes en entornos de realidad virtual y realidad aumentada. La Realidad Virtual (RV) y la Realidad Aumentada (RA) proporcionan sensaciones únicas conocidas como "Presencia", que engloba dos ilusiones: la Ilusión de Lugar (IL) y la Ilusión de Plausibilidad (IP). La IL es la ilusión de estar en el mundo virtual, mientras que la IP es la ilusión de que los eventos en el entorno virtual están sucediendo realmente. Con el creciente realismo de los escenarios virtuales, es esencial entender su impacto psicológico y los posibles efectos negativos, como el trauma o síntomas similares al TEPT. Este estudio nos ayudará a obtener una comprensión más profunda de cómo las experiencias en RV y RA influyen en las respuestas emocionales y fisiológicas. En este estudio, experimentará estímulos potencialmente intensos, como la presencia de un animal virtual, tanto en entornos de RV como de RA. Mediremos tanto las respuestas psicológicas como fisiológicas a estos estímulos para comprender mejor cómo se experimentan y su impacto en los usuarios.El estudio durará aproximadamente 40 minutos. Antes del experimento, responderá algunas preguntas. Durante el experimento, tendrá que responder algunas preguntas y completar una actividad que requiere el uso de equipo de realidad virtual (Meta Quest 3).
Durante el experimento, usará un visor de realidad virtual que presentará el entorno real en el que se encuentra actualmente, a través de cámaras adjuntas al visor, o experimentará un entorno virtual. En el experimento, verá frente a usted a un conejo, un perro o un lobo sentados. Ninguno de los animales atacará ni amenazará directamente en ningún momento, sino que permanecerán sentados frente a usted. En varios momentos, un elemento del entorno virtual cambiará (por ejemplo, se cambiará de la sala del mundo real a la sala virtual, o entre el perro y el lobo). Si acepta estos cambios o no, depende de usted.

Recuerde que puede abandonar el experimento en cualquier momento sin dar ninguna explicación. También puede pedirnos que eliminemos cualquier registro de sus respuestas. **Recuerde que será libre de abandonar el experimento en cualquier momento sin dar explicaciones.** También puede pedirnos que eliminemos cualquier registro de sus respuestas.

Se le pedirá que complete varios cuestionarios antes y después de las sesiones. Además, se medirá su ritmo cardíaco durante el experimento. Las mediciones son no invasivas y no suponen ningún riesgo para la integridad física. La información recopilada durante el estudio se difundirá de tal manera que no se le pueda identificar individualmente. En todos los informes de este trabajo (publicaciones científicas, congresos, etc.) su participación se discutirá como parte de un grupo y no se le mencionará como individuo. En caso de mencionar alguno de los comentarios o alguna de las respuestas de usted u otros participantes, siempre se hará de forma completamente anónima. Por su tiempo y cualquier inconveniente causado, se le compensará con 10 euros.

IMPORTANTE Cuando las personas usan un sistema de Realidad Virtual, a menudo experimentan una cierta sensación de náuseas. Si en algún momento del estudio desea detenerse debido a esto o a cualquier otra razón, por favor infórmenos y detendremos la experiencia inmediatamente. Algunas investigaciones sugieren que las personas que usan un visor de realidad virtual pueden experimentar alguna alteración visual menor poco después. No conocemos estudios a largo plazo, pero hay estudios de finales de la década de 1990 que sugieren que puede ocurrir un efecto posterior dentro de los 30 minutos. Sin embargo, el equipo de visualización de hoy está mucho mejorado. Con algunos tipos de videos, existe la posibilidad de generar un episodio epiléptico, como se ha informado que ocurre en algunos videojuegos. La Realidad Virtual Inmersiva puede tener influencias psicológicas y conductuales duraderas en los participantes. Dado que la realidad virtual se ha introducido recientemente al público, algunos riesgos pueden ser actualmente desconocidos. Sin embargo, en todos los estudios realizados bajo el grupo de investigación del Prof. Mel Slater durante las últimas 3 décadas, nunca se ha encontrado ningún efecto adverso de la tecnología en la psicología o el comportamiento.

Hallazgos Notables
El examen se realiza únicamente con fines de investigación. No se llevará a cabo una evaluación médica o psicológica de sus datos. Sin embargo, podríamos notar un

hallazgo inusual durante el examen. En tal caso, le informaremos y recomendaremos que este resultado sea evaluado más a fondo por su médico general. Solo puede participar en este estudio si está de acuerdo en ser informado sobre cualquier hallazgo notable. Si se diagnostica una condición durante esta evaluación diagnóstica, podría enfrentar posibles desventajas, como dificultades para obtener un seguro de salud privado o seguro de vida. Por favor, lea, entienda bien y firme su consentimiento informado. Recuerde que puede abandonar el estudio en cualquier momento sin dar ninguna razón. En caso de tener alguna pregunta o comentario relacionado con el estudio, por favor contáctenos: Prof. Mel Slater (melslater@ub.edu).

¡Gracias por su participación!

Demographics

Cuál es el número de identificación que le ha dado el experimentador?

[ ]

Cuál es tu género?

- ○ masculino
- ○ femenino
- ○ otro
- ○ Prefiero no decirlo

Cuál es tu edad?

[ ]

Cuánta experiencia tiene con la realidad virtual?

	1. Nunca	2	3	4. Ocasionalmente	5	6	7. Mucho
He entrado en la realidad virtual	○	○	○	○	○	○	○

Cuál es tu nivel de conocimiento en programación informática?

	1. Nunca	2	3	4. Ocasionalmente	5	6	7. Mucho
Mi conocimiento de programación es:	○	○	○	○	○	○	○

¿Cuántas veces en el último año has jugado a videojuegos?

	0	1-5	6-10	11-15	16-20	21-25	mas de 25
En el último año he jugado:	○	○	○	○	○	○	○

¿Cuántas horas has jugado a videojuegos en la última semana?

	0	1-2	3-4	5-6	7-8	9-10	mas de 10
En la última semana he jugado:	○	○	○	○	○	○	○

Block 4

CONSENTIMIENTO INFORMADO DEL PARTICIPANTE

Título del proyecto de investigación: El voluntario tiene que leer y contestar las preguntas siguientes con atención:

(Hay que rodear con un círculo la respuesta que se considere correcta) :

	Sí	No
¿Ha leído toda la información que le ha sido facilitada sobre este proyecto?	○	○
¿Ha tenido la oportunidad de preguntar y comentar cuestiones sobre el proyecto?	○	○
¿Ha recibido la suficiente información sobre este proyecto?	○	○
Ha recibido respuestas satisfactorias a todas las preguntas?	○	○
Has entendido que eres libre de abandonar este proyecto sin dar ninguna explicación y sin que afecte a tus derechos?	○	○
En cualquier momento	○	○
Sin dar ninguna razón	○	○
Ha comprendido los posibles riesgos asociados a su participación en este proyecto?	○	○
Está de acuerdo en participar?	○	○
Está de acuerdo en que sus datos personales sean tratados de acuerdo con la información proporcionada?	○	○

Block 5

Qué investigador te ha explicado este proyecto? (nombre y apellidos)

Block 6

Yo certifico: - que soy mayor de edad (18 años o más). - que no he consumido más de dos unidades de alcohol en las últimas 6 horas (2 unidades de alcohol = 1 cerveza o 2 copas de vino). - que no estoy tomado ningún tipo de medicación psicoactiva. - que no padezco epilepsia. - que no conduciré vehículos de motor o bicicletas, o ningún tipo de maquinaria que pueda causar peligro a mí mismo o a los demás, durante las 3 horas siguientes a haber acabado la experiencia de Realidad Virtual de este estudio. - que no padezco estrés postraumático o cualquier otro tipo de trastorno psicológic.

Please sign

× SIGN HERE

clear

Powered by Qualtrics

8.10. Elephant in the Room Post-questionnaire (ENG)

Demographics

What is the ID number given to you by the experimenter?

[ ]

What is your gender?

- Male
- Female
- Other
- Prefer not to say

Block 1

Please rank the combinations of rooms and animals from most disturbing at the top to least disturbing at the bottom, with the rest positioned accordingly between these two extremes. Drag and drop each combination to order them.

If you don't understand this please ask us.

Office + Wolf

Office + Dog

Office + Rabbit

Passthrough + Squirrel

Living Room + Dog

Passthrough + Dog

Office + Squirrel

Living Room + Squirrel

Living Room + Rabbit

Living Room + Wolf

Passthrough + Wolf

Passthrough + Rabbit

Block 2

Please make comments about anything you think is noteworthy about your VR experience. Things you could consider are: • Aspects of the experience that made you respond as if it were real. • Aspects of the experience that led you to make responses that would have been unrealistic if the situation depicted had been occurring in reality. • Aspects of the situation that suddenly disturbed your experience of being in the interview. • Aspects of the experience that helped or hindered you in achieving your task. • Aspects of your feelings towards the experience • Your views and feelings toward the animals involved. • Anything else you think is noteworthy to mention about your VR experience Write your answer in the space below:

Powered by Qualtrics

8.11. Elephant in the Room Post-questionnaire (SP)

Demographics

Cuál es el número de identificación que le ha dado el experimentador?

Block 1

Por favor, ordene las combinaciones de habitaciones y animales desde la más perturbadora en la parte superior hasta la menos perturbadora en la parte inferior, colocando el resto en consecuencia entre estos dos extremos. Arrastre y suelte cada combinación para ordenarlas.

Si no entiende esto, por favor pregúntenos.

Passthrough (Visión pasante) + Lobo

Oficina + Lobo

Passthrough (Visión pasante) + Conejo

Sala de estar + Lobo

Passthrough (Visión pasante) + Perro

Oficina + Conejo

Oficina + Perro

Sala de estar + Conejo

Oficina + Ardilla

Sala de estar + Perro

Passthrough (Visión pasante) + Ardilla

Sala de estar + Ardilla

Block 2

Por favor, comente cualquier cosa que considere digna de mención sobre su experiencia en realidad virtual. Algunos aspectos que podría considerar son: Aspectos de la experiencia que le hicieron reaccionar como si fuera real. Aspectos de la experiencia que le llevaron a hacer respuestas que habrían sido poco realistas si la situación representada hubiera ocurrido en realidad. Aspectos de la situación que repentinamente perturbaron su experiencia de estar en la entrevista. Aspectos de la experiencia que le ayudaron o dificultaron alcanzar su tarea. Aspectos de sus sentimientos hacia la experiencia. Sus opiniones y sentimientos hacia los animales involucrados. Cualquier otra cosa que considere digna de mención sobre su experiencia en VR. Escriba su respuesta en el espacio a continuación:

Powered by Qualtrics

8.12. Social VR Survey (Holoportation)

Appendix A: Social VR Questionnaire

Please answer the questions, according to your experience of watching the movie trailers.

The scale of the following questions are from 1 to 5, representing the following meanings:
1 Strongly disagree 2 Disagree 3 Neutral 4 Agree 5 Strongly agree

Strongly disagree 1 2 3 4 5 Strongly agree	**1**	**2**	**3**	**4**	**5**
1. "I was able to feel my partner's emotion while watching the trailer."	☐	☐	☐	☐	☐
2. "I was sure that my partner often felt my emotion."	☐	☐	☐	☐	☐
3. "The experience of watching the movie trailer with my partner seemed natural."	☐	☐	☐	☐	☐
4. "The actions used to interact with my partner were similar to the ones in the real world."	☐	☐	☐	☐	☐
5. "It was easy for me to contribute to the conversation with my partner."	☐	☐	☐	☐	☐
6. "The conversation with my partner seemed highly interactive."	☐	☐	☐	☐	☐
7. "I could readily tell when my partner was listening to me."	☐	☐	☐	☐	☐
8. "I found it difficult to keep track of the conversation."	☐	☐	☐	☐	☐
9. "I felt completely absorbed in the conversation."	☐	☐	☐	☐	☐
10. "I could fully understand what my partner was talking about."	☐	☐	☐	☐	☐
11. "I was very sure that my partner understood what I was talking about."	☐	☐	☐	☐	☐

Strongly disagree 1 2 3 4 5 Strongly agree	**1**	**2**	**3**	**4**	**5**
12. "I often felt as if I was all alone while watching the movie trailer."	☐	☐	☐	☐	☐
13. "I think my partner often felt alone while watching the movie trailer."	☐	☐	☐	☐	☐
14. "I often felt that my partner and I were sitting together in the same space."	☐	☐	☐	☐	☐
15. "I paid close attention to my partner."	☐	☐	☐	☐	☐
16. "My partner was easily distracted when other things were going on around us."	☐	☐	☐	☐	☐
17. "I felt that watching the movie trailer together enhanced our closeness."	☐	☐	☐	☐	☐
18. "Watching the movie trailer together created a good shared memory between me and my partner."	☐	☐	☐	☐	☐
19. "I derived little satisfaction from the trailer watching experience with my partner."	☐	☐	☐	☐	☐
20. "The trailer watching experience with my partner felt superficial."	☐	☐	☐	☐	☐
21. "I really enjoyed the time spent with my partner."	☐	☐	☐	☐	☐

See graphs below to indicate the emotional closeness	1	2	3	4	5
22. How emotionally close to your partner do you feel now?	☐	☐	☐	☐	☐

1 2 3 4 5

Strongly disagree 1 2 3 4 5 Strongly agree	1	2	3	4	5
[Questions 23-28 are not applicable for the real-world condition]					
23. "In the virtual world I had a sense of 'being there'."	☐	☐	☐	☐	☐
24. "Somehow I felt that the virtual world was surrounding me and my partner."	☐	☐	☐	☐	☐
25. "I had a sense of acting in the virtual space, rather than operating something from outside."	☐	☐	☐	☐	☐
26. "My trailer watching experience in the virtual environment seemed consistent with my real world experience."	☐	☐	☐	☐	☐
27. "I did not notice what was happening around me in the real world."	☐	☐	☐	☐	☐
28. "I felt detached from the outside world while watching the trailer."	☐	☐	☐	☐	☐
29. "At the time, watching the movie trailer with my partner was my only concern."	☐	☐	☐	☐	☐
30. "Everyday thoughts and concerns were still very much on my mind."	☐	☐	☐	☐	☐
31. "It felt like the trailer watching experience took shorter time than it really was."	☐	☐	☐	☐	☐
32. "When watching the trailer with my partner, time appeared to go by very slowly."	☐	☐	☐	☐	☐

Extra questions	Yes	No
33. Have you watched this movie before?	☐	☐
34. Did you like the movie trailer?	☐	☐

Thank you for your feedback!

8.13. Solutions and mitigations ethical considerations

Stakeholder	Theme	Subtheme	Ethical considerations per UC & theme: Professional collaboration	Manufacturing training	Health	Cultural heritage
End user	Accessibility & inclusivity	Hardware access & cost	Not everyone has access to high-end computers or VR headsets to fully engage. If the required equipment is too pricey, the experience is financially inaccessible.	High costs for high-end computers and other equipment.		
		Physical limitations hardware	Ensure that everyone can use and feel interactions, e.g., with haptics – use the haptic gloves and feel the feedback accurately, but also with the gloves being able to interact with objects in the environment.		Physical requirements for hardware, e.g., patients with physical disabilities or in need of different sizes of equipment might be excluded.	
		Onboarding support	For those who are not so experienced with VR or who are tech savvy, it might be difficult to know how to start and navigate/use the experience. These people will need support in these areas.	Provision of more instructions on what to do in the environment, why they are doing these tasks, and how to interact with objects to ensure everyone (even if different experience levels of VR) knows what to do and how.	Technical set up needs to be simple for _health care workers_ as it otherwise might take too much of their time. It should also be clear to the patients what they need to do and how, e.g., how catch the notes, but also how to use the controls (e.g., through a tutorial or step-by-step guide that's handy throughout the experience in case the patient forgets).	To help guide the users throughout the experience to tell them about the history and tasks as the user go through the experience, as it otherwise is easy to lose focus and forget what they have to do and how.
		Mobility & limitations		Although participants voiced that they would have liked to be able to move around more (i.e., have enough space to move freely in the real world), they liked the functions to move with the controls as people with limited mobility can still enjoy the experience.	People with visual restrictions might feel excluded, e.g., if they cannot wear their glasses under the headset or the environment itself might be overwhelming (e.g., in terms of colors and different things happening at the same time). Patients with autism or dementia might not feel included or enjoy this experience as it may be confusing for them and they might prefer to have more control over their surroundings (as they're not able to in a virtual environment). Concerns here revolved especially around how can we ensure that patients with autism can feel comfortable in this type of experience, and to what extent can these types of patients customize the experience to their needs?	People with physical limitations or phobias might not enjoy this experience as much, since they need to crawl (get down on their knees) to get through the tunnel (which can also trigger claustrophobia).
		VR sickness		Some people feel more/less cybersickness than others, thus it can be a barrier to complete the experience if it's too long or if it would make people feel sick.		Some participants mentioned that they felt a bit of cybersickness as they had to move in different positions throughout the experience, and that they felt disoriented.
		Representation	Ensure people of all ethnic backgrounds have equal representation.			
		Language barriers		When translating from one language to another, and especially when not well-versed in the other language, some meanings and important elements might get lost which may lead to some people not learning some procedures correctly or missing out on crucial information (especially if they would need to do the experience in another language not so familiar to them).		
		Adjustable settings		Adding game-like elements, such as mission/task boxes to tick, so it's clear for everyone what needs to be done and in what order.	For people who are more anxious, it would be beneficial to have difficulty level options of the game so they can be more/less distracted while doing their procedure. Then patients can choose themselves to what level they want to be distracted.	Comment that people with different physical needs/limitations or with different levels of experience with VR should be able to adjust the experience to fit their needs, e.g., volume settings, when digging to be able to do less motions or to adjust how heavy it is to dig, and to adjust difficulty level in general (if lower difficulty level there's more support throughout experience while in higher difficulty level the user can do more exploration and tasks themselves without support).
	Privacy & data transparency	Data collection, storage & use	Holoportation cameras capturing surroundings, concerns about what other users might be able to see if for example in a private space (e.g. at home). Concerns about the storage of body scan data, does anyone have access to the holoported images after the experience is completed and who?	Concerns regarding what is tracked, e.g., eye gaze, motion, etc. and how it's used.	Concerns about what data will be collected and how it will be used. In this case, how will giving consent work? If patients need to read documents and sign, it will take a lot of time and may not be feasible for smaller procedures like blood drawing.	Concerns about what type of data is collected and how it will be used.
		Role of AI	Can AI have access to holoportation body scan data?	Concerns around to what extent AI has access to any sort of data from the users, e.g., in terms of conversations.		
		Surveillance stress		As trainees know they're being watched by a trainer, they might become stressed and make mistakes or lose focus of why they're doing the training because they're trying to just do it perfect. Thus, the concern revolves around whether the trainees experiences are recorded/collected for them or the trainer to look at afterwards, and if this is known how it might impact the trainees and their stress levels.		

		Abuse & regulation		There were also some questions/concerns about what guidelines or rules there are to follow if a trainee would abuse the system, e.g., be rude to the IVA or other trainees? How are these actions tracked and how would this be taken care of?		In cases of e.g., abuse or misconduct in the experience, what regulations are there to deal with this and how will the "recording" of this data be handled and used?
	Cultural & historical integrity	**Accurate & respectful storytelling**				Strong emphasis on maintaining historical accuracy and authenticity in the VR experience, to avoid romanticizing or trivializing sensitive topics. Concerns were raised about the potential for the experience to manipulate or distort historical events and narratives. This was also something that was important to consider according to the participants in terms of education, as it intends to teach people about this time and event.
	Realism & functionality	**Dangerous practices**		Concerns regarding how realistic/graphic will it be if a trainee would do something in the experience that is dangerous, e.g., if they attempt to put their arm in the press to see the consequences.		
		Realistic learning		Concerns regarding interactions, if the trainee cannot move freely and realistically (as they would in the real world) how could they then learn the procedures correctly and safely?		
		Virtual representation			Concerns regarding physical realism in the environment, as the blood is drawn, how will this be visually represented in the virtual environment as the patient can feel it happening in the real world? If the patient can see what is happening to their arm, they can feel more immersed in the virtual environment (as otherwise this would break the immersion).	
Developer						
AI system provider/operator	Human agency					
	Transparency					
	Accountability					
	Discrimination					
	Robustness					

Stakeholder	Theme	Subtheme	Summary ethical theme	SOLUTIONS PER USE CASE					Who	When
				Professional collaboration	Manufacturing training	Health	Cultural heritage	ALL UCs		
End user	Accessibility & inclusivity	Hardware access & cost	High costs for hardware equipment (high-end computers, gloves, vests, VR headsets, etc).					- PRESENCE technologies should also work even if you do not have access to all HW components - Investing in hardware as possible threshold for the institutions is something taken into account also in WP6 in exploitation plan - identify in PRESENCE what is the minimum set-up (what is mandatory and what is necessary) and how open is our SDK	**WP 2, 3, 4, 6**	**Phase 3 + exploitation plan**
		Physical limitations hardware	Some hardware items might not fit all users, e.g., sizing, disabilities.					- PRESENCE SDK should allow different HW types from different manufacturers (e.g. making bigger vests or smaller gloves)	WP 3	**Phase 3 + exploitation plan**
		Onboarding support	Extra support in set-up of system, how to use the system (controls, navigation, and task instructions), support throughout experience.					- including tutorial before each experience to train users with interactions and with hardware - support during experience (depending on UC) - UX of the applications should include modes for inexperienced users, and guide them if they get stuck at one part of it	UC partners + WP 2, 3, 4	**Phase 3**
		Mobility & limitations	Adapted VR experiences and hardware to users with physical limitations and phobias/autism/dementia, e.g., option to move with controls, ensure glasses fit comfortably under headsets, customization options of VR environment.					- ensure that multiple options for interaction are available	UC partners	**Phase 3**
		VR sickness	Cybersickness due to time spent in VR environment and/or actions causing disorientation.					- introduce less artificial motions, e.g., joystick-based; - inform user about symptoms at beginning, e.g., via display screen / informed consent	UC partners	**Phase 3**
		Representation	Equal ethnic representation for avatars.					- generate set of diverse avatars: ethnically, gender, body types, etc.	WP 4 (DIDIMO)	**Phase 3**
		Language barriers	Exclusion due to translation issues or lack of familiar/mother tongue languages.					- LLM can also be used to translate or simplify language	WP 4 (UHAM)	**Phase 3**
		Adjustable settings	Adjustable settings such as adding game-like elements, difficulty level options, volume settings...					- ensure that these options are available	UC partners	**Phase 3**
	Privacy & data transparency	Data collection, storage & use	Concerns about what data is collected, stored, and used. E. g., imagery, biometric data...					- provide informed consent screen at beginning of screen; - providing about/information through settings/preferences; - provide option to inspect data that is used by the system	UC partners	**Phase 3**
		Role of AI	Concerns about AI use and what it has access to.					- provide informed consent screen at beginning of screen; - providing about/information through settings/preferences; - provide option to inspect data that is used by the system	UC partners	**Phase 3**
		Surveillance stress	Concerns about to what extent trainees are "surveilled" by trainers, during or after sessions.					**If we collect data we need to provide access to user to decide what they want to happen to their data (e.g., delete)**	UC partners	**Explotation phase**
		Abuse & regulation	Regulations around misconduct and abuse, and how is this data"recorded" and handled.					**At the moment, no data is recorded, if that's the case we can start thinking about regulations**	All	**Explotation phase**
	Cultural & historical integrity	Accurate & respectful storytelling	Ensure accurate and respectful storytelling.				Disclaimer: is the experience historically accurate or is it fictional? When accurate provide some references		Zaubar	**Phase 3**
	Realism & functionality	Dangerous practices	Graphic depictions of consequences of actions.		No real depictions, but add warning message stating consequences or a sound or haptic feedback to signal the user should not do that action				Vection	**Phase 3**

		Realistic learning	Concerns about realistic learning.					Ensuring movement options for users alongside controllers	UC partners	**Phase 3**
		Virtual representation	Visual representations of real world in virtrual world.			Possible to add option of 'pass through'			SyncVR	**Phase 3 / exploitation phase**
Developer										
AI system provider/operator	Human agency		Risk of attachment to virtual human							
			Risk of addiction to experience							
			Over-reliance on AI, risk of manipulation							
	Transparency		Lack of transparency about data and process used for training AI models							
			Privacy concerns when using cloud-based AI services							
	Accountability		Options to provide feedback on unexpected functioning, situations where users felt unsafe, etc.							
	Discrimination		Possible bias and discrimination in LLM responses							
	Robustness		Deployment context moves away from validated scenarios							

8.14. PRESENCE Evaluations activities manual

PRESENCE Evaluation activities manual

This document provides the procedures and guidelines for testing the PRESENCE UC apps in the third phase of the PRESENCE project. This manual applies to all evaluation activities involving users (end users and professional users). By standardizing the research setup and activities, we increase our chances that test results across UCs and testing moments, as well as participants, are comparable, and that theoretical saturation will be reached.

Preparation is key to organizing a successful research activity. Therefore, we emphasize the importance of reading this manual carefully, preparing the needed digital documents (drop-offs, informed consent forms, etc.) and testing the recording equipment. This will help the facilitators, and ensure a successful session.

The goal of this exercise is to receive feedback and insights about the PRESENCE UC apps. We aim to gather insights about what users think of the apps and technology and what they need and want from them. These insights and feedback will help guide the further development of the project technologies.

Preparing the sessions

Specifying the informed consent form

In preparing for the sessions, it is important to take a look at the informed consent form and specify the following information:

- **Project overview:** Clearly explain the PRESENCE project, its aims and innovative use of VR technology.
- **Purpose of research:** State the purpose of the research activity and specific objectives.
- **Criteria for participants:** State demographics and other criteria for selecting participants.
- **Participation details:** Provide details on the duration, tasks and commitment required of participants.
- **Compensation:** Inform participants about any compensation or incentives.
- **Data collection:** Describe what types of data will be collected and how it will be used.
- **Data privacy:** Provide information about data privacy, including who stores the data and who has access to it.
- **Participants' rights:** Clearly state participants' rights, including the right to withdraw at any time without cause.
- **Potential risks:** Inform participants of potential risks, especially those associated with the use of virtual reality.
- **Ethical considerations:** Ensure that participants are fully informed and give explicit consent
- **Inclusion and diversity:** When recruiting participants, emphasise efforts to ensure inclusion and diversity.
- **Communication:** Ensure open communication so that participants are fully informed about all aspects of the study.
- **Access to publications:** Provide information on where participants can find articles, blog posts and results published by the project.
- **Follow-up:** Explain that participants will not be contacted about further research activities unless they have given explicit consent.

An informed consent template was published in deliverable *D1.1 Human centred development Phase I*, it should be adjusted to reflect the correct responsibilities of the partner conducting the experiments and the correct procedure for sharing data as this can differ per test.

Data sharing agreement and ethical approval

As the PRESENCE project consortium aims to maintain the highest ethical standards recommended by professional bodies, institutions, and governments both during user studies and when generating, collecting, or re-using data, it is important to investigate whether ethical approval for certain activities is needed. In deliverable *D7.1 Ethics framework and data management plan I*, you can find more information about what is important to pay attention to when assessing whether an ethical approval is needed and how to go about obtaining such.

It is also important to in advance consider whether you will be making video or photo material from the sessions, and whether another partner will have access to the non-anonymized/pseudonymized material. In this case, a data protection agreement (DPA) must be in place between the concerned partners, see deliverable *D1.2 Human-centred development phase II* for a DPA template.

Recruitment of participants

During these sessions, it is important to ensure a diverse set of participants (e.g., gender balance, educational/professional background, technical background, etc.). It is also important to begin recruitment efforts on time, to ensure that the expected participation goal is reached. Normally 2 weeks in advance should suffice to start recruiting participants, this can be done within your organization or inviting the target group (end users or professional users) through sharing the call for participation within your own or the project networks, e.g. LinkedIn/social media.

Setting up the sign-up procedure

As you're making the call for participation, the following points should be included:

- What is the goal of the session and invitation
- Possible selection criteria, e.g., who can attend (students, professionals …), do they need prior experience with VR, etc.
- When and where the session takes place
- If there's an incentive for participation (optional)
- How they can sign up to participate

To ensure a deep understanding of the users' experience per testing phase, we recommend aiming for at least 10 participants per UC. If you decide to recruit through direct invitation to specific people, aim to invite at least 2 more people than the intended number. When setting up the time slots, it is important to also ensure some time in between tests for the facilitators to catch their breath and to have some lay room in case one session goes over-time. To have an overview of who signs up for what time, we recommend setting up a Doodle sign up sheet (or Calendly).

As participants sign up for one of the sessions, they should be sent a confirmation email thanking them for signing up and outlining all necessary information for their session (such as date, time, duration of the session, location, contact information to facilitator(s)). The day before the test a reminder can be sent to the participant.

During the sessions

Facilitators: role and tasks

The experience facilitators main task is to ensure that the testing of the experience runs smoothly. They will also be conducting the interviews with the participants.

Experience facilitator #1

Experience facilitator #1 should be present with the participant in the room when they are testing the VR experience. This person tells the participant what will happen in the test and should be able to help the participant enter and calibrate the experience. During the experience, the experience facilitator #1 may also make observation notes, as these can help remembering what happened during the testing (if the participant had a specific question or remark at a certain point of the experience) and to give more context to what the participant refers to during the interview.

This person should also conduct the interview with the participant after the experience has concluded. It is crucial that the experience facilitator #1 asks open and non-leading questions, as the aim is to understand the motivations and personal experiences of the participants.

Example biased/leading question: *Did the app run smoothly without any bugs or glitches?*

Example of open and non-leading question: *Did you encounter any technical issues or performance problems during the session?*

It is normal that the participant may touch upon different questions (listed in the topic list), in this case the facilitator should let the participants freely discuss without interference. But in case the subject shifts away from the topic list, it is important to get the conversation back on the right track in a gentle way.

Experience facilitator #2

Experience facilitator #2's has the same task description as experience facilitator #1, during the multi-user tests. During single-user tests, experience facilitator #2 instead has the responsibility of experience facilitator #3.

Experience facilitator #3

During multi-user tests, we highly recommend having a third facilitator present as participants may show up while the other two facilitators are still conducting interviews with other participants. Experience facilitator #3's main purpose is to bring each participant from the entrance to the right room. In the case where the other facilitator(s) is still conducting interviews, the responsibility also includes ensuring the participants sign all necessary forms, as well as introducing what the test is about. It is important that this person keeps a close eye on the schedule to ensure that each participant is welcomed at the right time.

Making notes

Although we will be voice recordings and transcripts of the sessions to capture what the participant says, it's also useful to have observation notes from each session to capture what the participant does and how participants address and interact with each other.

Here are some key things to think about:

- If possible, try to make some observation notes during the experience, especially of behavior of the participants and whether there are some things that are difficult/frustrating/going well etc for them.
- How you choose to make notes is very individual, some prefer to make digital notes and others prefer to make handwritten notes - in the case of the latter: please try to write as clearly as possible so that it is readable during the analysis.

After each session, notes will be put in word documents on the Sharepoint - but if there are handwritten notes these should be photographed and put on the Sharepoint as well.

Audio recording and making photos and videos during sessions

During the testing sessions, audio recording is mandatory. This is to ensure that we fully capture the participants' feedback. These audio recordings should be stored locally and securely with the partner who organized the experiment; it is crucial that data storage is in line with the guidelines of the project's data management plan.

As mentioned in the chapter on preparing the sessions, it is also possible to make photos and videos of participants as they are testing the UC apps. However, it is crucial to inform participants of this, both through the informed consent form and by verbally asking for their consent before taking a photo or video. These photos and videos must ensure that no personal information about the participant is revealed, and all material must be anonymized before it can be used. In cases where the data is shared between partners and especially where it has not been anonymized or pseudonymized, a data sharing agreement (DPA) must be in place between the concerned partners to ensure that GDPR standards are upheld.

Part 1: Registration & testing the UC apps (30 min)

First, it is good to start by introducing yourself as well as giving a brief introduction to explain the PRESENCE project, and why participants' involvement is important. Second, due to GDPR regulations, each participant needs to sign an informed consent form, one for the organizer and one for the participant to bring home. The facilitator(s) needs to briefly go over the content of the informed consent document with the participants, so participants fully understand the content of the document.

It is important to emphasize the following points:

- Participants can always quit the research activity at any given moment
- Participants are allowed to ask to delete all their collected data and other information at any point by contacting the researchers (names and contact details are in the form)
- Their actions will be recorded and transcribed for research purposes only. Video nor audio will be published as such. Visuals created during the session can be published but will never contain personal information on the participants.
- Explain how the data will be handled: e.g., only by the researchers, none of the personal information will be shared. Participant names and personal information will be pseudonymised, all outdated or irrelevant data will be deleted. The data will only be used considering the PRESENCE project activities, not for other (research) purposes.
- Their data will never be shared with any third party, and within the projects' consortium, only researchers have access to the data.

After the informed consents have been read and signed, the participant should also sign a sign-in form. Then, you can start by explaining the context of the UC apps (i.e., the scenario in which the participants finds themselves). You should also help the participant put on and calibrate all required hardware equipment, as well as introducing how they use the equipment (e.g., for navigation). As the participant is testing the UC app, encourage them to share their thoughts as they go and that they can ask questions if needed. After the experience is concluded, the participant shall fill out the UX survey by UHAM, this can be done on a PC or through a QR code on the participant's own phone.

List of material:

- Informed consent form
- Sign in sheet
- UC apps + required hardware equipment

- Link/QR code to UX survey

Creating a safe space

It's important in this activity that participants can feel comfortable sharing their opinions and thoughts openly with the interviewer. Not everyone is equally comfortable or experienced with VR technology or the technical pillars of the project, and thus it's crucial that the facilitator clearly explains how the technology and applications work, how they can navigate through the experience, what they will see and do, etc. This can help the participant feel more comfortable in the experience, but also build trust with the facilitator. It's important that the facilitators 1 and 2 make clear at the beginning of the experience and interview that the participant is there to test the experience, not that they are being tested, and that there are no wrong answers.

Part 2: Interview (30 min)

After the testing of the UC apps and the filling out of the UX survey, the interview can start. Now it is important to again tell the participant that this part of the session will be recorded, and then you start the recording. During the interview, the participants will first be asked to reflect on their first impressions of the UC app: what did they like or dislike in particular and what stood out to them. Then they will be asked to reflect on UX and social presence, answering questions about navigating the experience, interacting with the technical pillars and other users, as well as how immersed and present they felt in the experience. In the delivered topic list, you will find more specific questions and probing questions to be asked during the interview. Before concluding the interview, the facilitator must ask the participant whether they have anything more to add before wrapping up. After concluding the session, the participant shall sign a sign-out sheet where they can also indicate whether they received the incentive (if applicable), that they want to be updated on the results of the research, and if they want to be invited to future activities within the project.

List of material:

- Recording device
- Topic list (provided by IMEC)
- Sign out sheet

After the sessions

Translating material

Sessions and interviews can be held in any language, but it's important that transcripts from the recordings are translated to English before sent to IMEC. For the translation, partners can use tools such as Deepl, an online tool that is capable of translating large files. The translation of transcripts is the responsibility of the organizing partner as they directly can ensure that translations are correct.

Pseudonymised transcripts and other material with user input (e.g., anonymised pictures of the test setup, pictures of material that participants worked with such as post-its, etc.) must be uploaded to the IMEC-SMIT external Sharepoint as soon as possible after the session. The organizing partner must share their contact information with IMEC so that access to this folder can be granted.

Materials overview

For these sessions, the following material is required:

General:

- Participant list
- Sign in and out sheet
- Informed consent forms
- Incentives (if applicable)

UX survey:

- Online (done on participants' phones or organizer's computer)
- Printed QR code to access questionnaire

Test session of PRESENCE app:

- Pen and paper for experience facilitators to make notes (participants can also use pens to sign forms etc)
- HMDs and controllers (2 sets per app test session)
- glove and haptic vest
- cameras for holoportation
- Monitor/computers per app test session

Interview:

- Topic list (provided by IMEC)

8.15. Letter of Intent

PRESENCE Letter of Intent for Collaboration in Technology Testing

To Whom It May Concern,

I, [first- and last name], express my intent to collaborate with the PRESENCE consortium as a facilitator for testing the [UC name] at [institution/organization]. This letter confirms my commitment to support three key phases of technology evaluation:

Phase 1: Technology Demonstration

I will provide the necessary resources and environment for demonstrating the technology to stakeholders at [institution/organization].

Phase 2: Volunteer Testing

Post-demonstration, I will organize and oversee tests with volunteers to assess the technology's effectiveness and usability.

Phase 3: Ethics Committee Review and Extended Testing

I will assist in obtaining ethics committee approval for further, more comprehensive testing scenarios, provided that the ethics application letter is provided by the PRESENCE consortium. This Letter of Intent affirms my support for introducing and evaluating this technology at our institution, with the [goal of….].

Sincerely,

[first- and last name]

[institution/organization]

[signature]

8.16. DPA template

DATA PROCESSING AGREEMENT

Between

INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM (IMEC), a non-profit organization under Belgian law, having its registered office at Kapeldreef 75, B-3001 Heverlee, registered at the KBO under number 0425.260.668 and duly represented by ________________.

And

[PARTNER NAME], a [COMPANY DESIGNATION] under [APPLICABLE LAW], having its registered office at [ADDRESS], registered at the [COMPANY REGISTER] under number [NUMBER], duly represented by ____________.

The Parties hereinafter jointly referred to as "**Parties**" and separately as "**Party**".

CONSIDERING THAT:

According to the General Data Protection Regulation (EU) 2016/679 ("**GDPR**"), **IMEC VZW** is qualified as the controller (hereinafter referred to as "**Controller**") who is responsible for the personal data which is subject to the Processing activities in the frame of this DPA, and **[NAME PARTNER]** is qualified as the processor (hereinafter referred to as "**Processor**"), who will process Personal Data on behalf of the Controller. To comply with the GDPR, Parties wish to enter into this DPA, which covers their respective rights and responsibilities towards the personal data.

IT HAS BEEN AGREED AS FOLLOWS:

1 Definitions

1.1 "**GDPR**" shall mean General Regulation Data Protection (EU) 2016/679.

1.2 Following terms shall have the meaning attributed to it under the GDPR: **Controller**, **Processor**, **Personal Data**, **Processing**, **Data Subject** and **Personal Data Breach**.

1.3 "**DPA**" refers to this agreement, including all (possible) appendices and amendments.

1.4 "**Subprocessor**" means a natural or legal person, public authority, agency, or other body which processes personal data on behalf of the Processor.

2 Scope

2.1 Processor processes the Personal Data exclusively under orders of and in accordance with Controller's written instructions and for the purposes identified by Controller. Processor will inform Controller if, in its opinion, an instruction infringes the GDPR or other applicable law. Processor processes the Personal Data in accordance with the method laid down in **Appendix 1**.

2.2 Processor may not process the Personal Data for third parties, for its own requirements and/or for any other purposes and may not process the Personal Data any longer than is strictly required for the purposes as described in **Appendix 1**. Processor will implement the measures stipulated in Article 9.2 when the Processing of the Personal Data related to this DPA ends.

2.3 Controller will remain the Controller at all times and will be entitled to the Personal Data. Considering the processing activities laid down in **Appendix 1**, Controller has the last say in the level of anonymization by Processor and for that purpose, Processor will provide a sample. If Controller decides that the level of anonymization is not sufficient, Processor will apply additional anonymization techniques until Controller decides that the final data set is sufficiently anonymous.

2.4 Processor assures that there are no obligations arising from applicable laws that would prevent Processor from complying with the obligations of this DPA.

3 Transfer and Subprocessors

3.1 Processor shall not transfer the Personal Data to any third parties without prior written consent from Controller unless required by Union or Member State law to which Processor is subject. In such a case, Processor shall inform the Controller of that legal requirement before transferring, unless that law prohibits such disclosure.

3.2 Processor shall not engage a Subprocessor without prior written authorisation of Controller. Controller has the right to make this authorisation dependent on reasonable conditions and can request a list of all Subprocessors at all times. Such Subrocessor shall process the Personal Data under the sole supervision and the full responsibility of Processor.

3.3 If Processor employs a Subprocessor, Processor will agree with Subprocessor the same contractual obligations as agreed between Controller and Processor in this DPA, especially the obligations set forth in article 3.2, 3.4 and 6 of this DPA.

3.4 Processor shall not transfer the Personal Data to countries or international organisations outside the EEA, except on written instructions from Controller. Processor shall ensure that appropriate safeguards in accordance with Chapter 5 (article 44 – article 50) GDPR are in place.

4 Assistance and co-operation

4.1 Whenever a Data Subject wants to exercise their rights or has questions relating to the Processing of their Personal Data, Processor will transmit this request or this question without undue delay and no later than five (5) working days to Controller for further handling. Processor will abstain from direct contact with the Data Subject unless Controller has instructed otherwise.

4.2 Taking into account the nature of the Processing activities, Processor shall take adequate technical and organisational measures to provide Controller with full co-operation and assistance in relation to any Data Subject request.

4.3 Taking into account the nature of the Processing activities, Processor shall assist Controller with:

- Keeping the Personal Data secure;

- Notifying Personal Data Breaches to the supervisory authority;
- Notifying Personal Data Breaches to the Data Subjects;
- Carrying out data protection impact assessments;
- Consulting with the supervisory authority when there is high risk;

As provided for in the articles 28.3 (f) and 32 through 36 of the GDPR.

5 Notification Obligation

5.1 Processor shall actively screen for any Personal Data Breach. As soon as a Personal Data Breach has occurred or could occur, Processor will inform Controller hereof immediately, or, in any case, not later than 48 hours after having learned of the potential Personal Data Breach. This notification will contain at least the following information:

- The (suspected) cause of the Personal Data Breach;
- The nature of the Personal Data Breach;
- The known and/or the likely consequences of the Personal Data Breach;
- The category and approximate number of Data Subjects concerned;
- The measures taken or proposed to be taken by the Processor to address the Personal Data Breach and/or to mitigate its possible adverse effects.

5.2 If the Processor uses a Subprocessor, the Processor shall require the Subprocessor to provide them with the same information if a Personal Data Breach occurs at the Subprocessor. The Processor shall immediately transmit the information received from the Subprocessor to the Controller.

5.3 Processor shall assist Controller at any time, to allow Controller to thoroughly investigate the Personal Data Breach, to remedy the consequences of the Personal Data Breach and to follow up on the Personal Data Breach.

5.4 Processor will keep Controller informed of any new developments concerning the Personal Data Breach and of any measures taken by Processor to mitigate the consequences of the incident and to avoid a new occurrence.

5.5 Processor will not notify the Personal Data Breach to the supervisory authority and/or the Data Subjects without the prior written consent of Controller.

5.6 The information or the notification of the Personal Data Breach to the supervisory authority and/or the Data Subjects is the responsibility of Controller as described in art. 33.1 GDPR.

5.7 The Processor shall immediately notify the Controller of any request, order, investigation or citation addressed to the Processor or its Subprocessor by a competent national governmental or judicial authority that involves the communication of Personal Data processed by the Processor or a Subprocessor or any data and/or information related to such Processing by the Processor for and on behalf of the Controller.

6 Security

6.1 The Processor shall implement and maintain adequate technical and organisational security measures. These measures shall, with due regard for the state of the art and the costs involved in the implementation and execution of the measures, guarantee an adequate level of protection, allowing for the risks involved in Processing Personal Data. These adequate technical and organisational security measures correspond at least with those specified in **Appendix 2**. Maintaining these technical and organisational security measures is an essential condition for this DPA. A breach of the technical and organisational security measures will entitle Controller to terminate this DPA.

6.2 Controller can audit the observance of the technical and organisational security measures up to once every calendar year, and also whenever Controller has reasonable grounds to believe that Processor is in breach of this DPA and/or the provisions of the GDPR. Controller will inform Processor hereof at least fourteen (14) days in advance and Processor will provide all reasonable assistance to such audit. Controller shall ensure that audits will be conducted during normal business hours, at Processor's principal place of business or other location(s) where the Personal Data is accessed, processed, or administered. Processor will provide all information that is necessary to demonstrate compliance with the obligations laid down in art. 28 GDPR. The cost of the auditors shall be for Controller. They will be borne by Processor if the audit would reveal that Processor substantially fails to implement the agreed technical or organisational security measures or fails to meet its obligations under the GDPR, in particular its obligations under art. 28.

6.3 Processor will remedy as soon possible and at its own expense any breach of its obligations under this DPA and will inform Controller thereof. Controller reserves the right to terminate the DPA when Processor is in breach of its obligations under this DPA and under the GDPR.

7 Confidentiality and secrecy

7.1 Processor shall treat the Personal Data as confidential information and process this Personal Data carefully in accordance with the GDPR and other applicable regulations.

7.2 Processor shall disclose the Personal Data solely to employees or Subprocessors on a strict need to know basis.

7.3 Processor shall also ensure that all required recipients of the Personal Data shall respect the obligations laid down in this DPA, including the obligations of security and confidentiality. In the absence of sufficient statutory confidentiality obligations, Processor shall himself provide for adequate confidentiality provisions.

8 Liability

8.1 The Parties acknowledge that any Data Subject, who has suffered damage as a result of any breach of the obligations under this Agreement by Controller, Processor or any subsequent Subprocessor, is entitled to receive compensation from the breaching party for the damage suffered. The Parties shall be severally liable for their own acts. The liability of the subsequent Subprocessor shall be limited to its own Processing operations.

8.2 Processor shall be liable to Controller for any breach of this Agreement by itself or any Subprocessor appointed by Processor to the extent that such breach is not contributed to or caused by any breach of this Agreement by Controller.

Controller shall be liable to Processor for any breach of this Agreement to the extent that such breach is not contributed to or caused by any breach of this Agreement by Processor or any of its Subprocessors. This article is intended to apply to the allocation of liability for losses as between the Parties, including with respect to compensation to Data Subjects, except:

- If it is not permitted by applicable law (including the GDPR); and
- If it relates to the liability of either Party to any Data Subject.

9 Term and termination

9.1 The present DPA becomes effective on the date on which it is signed by both parties ("**Effective date**") and shall remain in force until__________.

9.2 Without prejudice to specific provisions to the contrary in this DPA and without prejudice to any applicable legal obligations, all Personal Data and all copies thereof need to be returned immediately upon Controller's first request, or the Processor, as Controller prefers, shall destroy all Personal Data when this DPA ends. Processor will provide proof that the Personal Data and all copies thereof are properly deleted upon request of the Controller.

9.3 Provisions arising from this DPA which by their nature are intended to continue following the termination of this DPA, will continue following termination of the DPA. These provisions include: the articles 7, 8, 9 and 10.

10 Other provisions

10.1 This DPA shall be governed by and construed in accordance with the laws of Belgium, without its choice law provisions.

10.2 All disputes between the Parties in connection to this DPA shall first be discussed in good faith between the Parties in order to try to find an amicable solution. Failing to reach an amicable solution, the Parties agree to submit the dispute to the competent and exclusive courts of Leuven, Belgium, and each Party irrevocably submits to the exclusive jurisdiction of such courts in any such dispute, action or proceeding.

10.3 Processor is not entitled to transfer its rights and obligations from this DPA to a third party without Controller's prior written consent. Any consent may be subject to conditions in the interest of the protection of the Data Subjects, or in the interest of Controller.

10.4 This DPA is severable and if one or more provisions, which are not the essence of the DPA, are declared invalid, the validity of the other provisions shall not be affected. If any provision of this DPA is deemed to exceed legal limitations, that provision shall be enforceable to the maximum extent permitted by law. If any part of the DPA is considered completely invalid, the Parties shall negotiate new provisions which are as similar as possible in terms of economic effect of the invalid provision.

10.5 Deviations from and supplements to this DPA shall only be valid if they have been explicitly agreed in writing between the Parties.

10.6 The signature of a Party to this DPA via a scanned or digitized image of a handwritten signature (e.g. scan in PDF format) or an electronic signature (e.g. via DocuSign), shall have the same force and effect as an original handwritten signature for the purposes of validity, enforceability, and admissibility. Each Party receives a fully executed copy of the DPA. Delivery of the fully executed copy via e-mail or via an electronic signature system shall have the same force and effect as delivery of an original hard copy.

IN WITNESS WHEREOF, the Parties hereto have caused this DPA to be executed by their duly authorized representative on the dates specified below:

For IMEC	For [PARTNER NAME]
Name:	Name:
Title:	Title:
Date:	Date:

Appendix 1: Overview Processing of Personal Data
Appendix 2: Minimum technical and organisational security measures

Appendix 1: Overview Processing of Personal Data

A. Purpose and nature of the Processing	The Processor has the right to process the Personal Data in so far and to the extent that this is necessary to carry out ___________.
B. Categories of processed Personal Data	☐ Identification information ☐ Financial information ☐ Contact information ☐ Family information ☐ Connection information ☐ Geographic information ☐ Education and professional information ☐ Physiological information ☐ Behaviour information ☐ Information regarding health ☐ Racial or ethnical origin ☐ Sexual orientation ☐ Trade union membership ☐ Philosophic, political or religious beliefs ☐ Photographic, [PARTNER NAME] recordings or video footage ☐ Judicial information ☐ Genetic data ☐ Biometric data
C. Categories of Data Subjects	☐ Employees ☐ Family members of employees ☐ Candidates ☐ Research subjects ☐ Stakeholders ☐ Customers ☐ Prospects ☐ Suppliers ☐ Visitors
D. Privacy contact information	[contact information regarding privacy of Processor]

Appendix 2: Minimum technical and organisational security measures

The Processor should take adequate technical and organisational security measures to protect the Personal Data that the Processor processes, including the Processing of Personal Data from the Controller. These technical and organisational security measures consist of, but are not limited to, the following actions:

Organisational measures

- **Information security policies** – Processor must have the appropriate information security policies in place, including, but not limited to, an information security policy, a password policy, a remote access policy, a data classification policy and an incident management policy.
- **Personal data policies** – Processor must have the appropriate policies and procedures in place with regards to the Processing of Personal Data such as, but not limited to, a Personal Data Breach procedure, a Retention policy, and a Personal Data protection policy.
- **Business Continuity** – Processor should have protocols and measures in place to back-up Personal Data and ensure that it can be recovered and maintained in the event of an incident.
- **Awareness & Training** – Processor must have a culture of security and data protection awareness to ensure that its employees, contractors and any third-party working for or with the Processor know what is expected of them and how they should maintain compliance. Regular and ongoing training sessions will ensure that they receive the latest information, guidance, legislations, and regulations and that these are known and understood.
- **Reviews & Audits** – Processor must regular review or audit the Processing activities to ensure compliance with the applicable legislation and policies.
- **Management Information & Reporting** – Processor regularly reports to upper management to ensure that the adequate resources and funding are made available and that there is accountability at all levels.
- **Contracts** – Processor meets all contractual obligations linked with the Processing of Personal Data such as, but not limited to, non-disclosure agreements, data processing agreements and contractual agreements with employees.
- **Roles and responsibilities** – Processor has appointed (a) person(s) or group(s) responsible for privacy and for information security.

Technical security measures

- **Information security program** – Processor has an information security program in place to ensure an adequate level of data security.
- **Logging** – Processor must have sufficient logging in place that can be used to determine who did what and when in case of a Personal Data Breach.
- **Monitoring** – Processor must monitor its IT environment on malicious actions or technical issues that can lead to, or are a result of, a Personal Data breach.
- **Authentication and authorisation** – Processor must have systems in place that limit the access to Personal Data only based upon the necessity of the employee. These systems must meet the current market standards with regards to strong authentication.
- **Patching and anti-virus** – Processor must patch its systems regularly and have an up-to-date anti-virus software in place.
- **Encryption** – Personal Data must be stored on encrypted devices and may only be transmitted via secure communication channels.
- **Firewall** – Processor must have adequate security measures in place to protect its network including an up-to-date firewall.
- **Physical security measures** – Processor must have physical measures in place to ensure that the Personal Data is secure. These measures can include, but are not limited to, physical access control, and measures in case of fire, break-in, or water damage.