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SHARESPACE

Embodied Social Experiences in Hybrid Shared Spaces

PROJECT REFERENCE NO	101092889
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WORKPACKAGE	WP6. SYSTEM INTEGRATION, REAL-WORLD SCENARIOS, AND VALIDATION
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INVOLVED INSTITUTIONS	DFKI, ALE, CdRC, UM, UJI, VHIR, INRIA, AE, GOLAEM, CYENS, RICOH, DMU
DOCUMENT DESCRIPTION	This deliverable reports the logistical, administrative and technical preparation of real-world scenarios with relevant Institutions: Pain Unit Of Hospital Vall d'Hebron for HEALTH, Paris 2024 Summer Olympics and Tour De France 2025 for SPORT, Ars Electronica Festival 2024 and 2025 for CREATIVITY.

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Table 1: List of Abbreviations

Term / Abbreviation	Definition
AI	Artificial Intelligence
CA	Cognitive Architecture
NN	Neural Network
PoP	Proof of Principle
RL	Reinforcement Learning
VH	Virtual Human

2 INTRODUCTION

2.1 PURPOSE OF THE DOCUMENT

One of the key objectives of SHARESPACE is the Real-World Scenarios Evaluation (led by UM) of our three Real-World Scenarios in embodied hybrid social space in three high-impact areas of deployment - Health (Social Low Back Pain Exergame), Sport (Peloton Cycling), and Art (Shared Creativity). Descriptions of the scenarios are provided under hyperlinks.

Together, these three scenarios will test all levels of autonomy - from human representation at avatar level (L1 and L2), to virtual autonomous character. To demonstrate the efficacy of our architecture, with respective KPIs. The scenarios have been selected based on the expertise of our consortium (VHIR for Health, INRIA for Sport, and AE for Art) and upcoming international events where they will be demonstrated: The World Congress on Pain (2024 and 2025) held by the International Association for the Study of Pain (IASP), the Olympic Games in Paris (July 2024) and the Tour de France (July 2025), and the Ars Electronica Festival (September 2024) and a dedicated event in Linz in 2025.

The research delivery roadmap has been produced and is iteratively updated for all of the SHARESPACE scenarios to monitor delivery. As the implementation of new systems and technologies introduces certain risks that need to be carefully evaluated and mitigated, we have run a systematic process to identify, analyze, and prioritize potential risks associated with the implementation of SHARESPACE technology across the three different scenarios (concluded in a deliverable D1.2 Research Requirements and D8.1 Risk Log). By examining these risks, we identified the potential challenges and uncertainties that may arise during the implementation process and developed effective risk management strategies as a part of the user requirements and technical safety rules.

2.2 STRUCTURE OF THE DOCUMENT

We describe the most recent version of each scenario, updated from the proposal description. We attach the timeline for the deployment of the system, the technology needed to be employed, involved partners, the main metrics used for assessment, and a recap of the risk mitigation scenarios. We close the document with the questionnaire repository we have built for this work.

3 SHARESPACE FOR HEALTH

3.1 SCENARIO DESCRIPTION

Mireia is 42 and Ricardo is 61, they both suffer from chronic low back pain and are outpatients at the Pain Unit in the Vall d'Hebron hospital. Chronic pain has had a profound impact on their lives. Mireia stopped her job one year ago and is supported by her partner. Ricardo is trying to get an early retirement and as he is not able to work right now, he is on prolonged sick leave. Both have also significantly reduced their social life and physical activity. They complain of feeling constant pain, fatigue, low mood, and fear of movement. At the hospital they can attend group physical therapy sessions, which helps them, but is difficult to sustain. The rehab sessions are programmed at a fixed time and the hospital is far from their homes. In addition, given the limited resources at the hospital, groups are too large and the physical therapist cannot personalize the exercises. Mireia likes the group sessions, because it is fun to be with other people and she feels more motivated and hopeful. Ricardo would prefer to have more personalized sessions to correct his postures and perform the exercises more effectively.

Phase I (VR): For the first time Mireia and Ricardo can perform the physical therapy sessions from home. They have been enrolled in exercise sessions conducted remotely with Judith (their physical therapist based at the Rehab Unit). Together with other outpatient at the same time (two at once) located in the hospital (with VR headset/sensors/computer units connected to the network), they join the session using the SHARESPACE platform and a VR headset (the other patients are at the hospital and follow the session in the traditional way). During their virtual session Mireia and Ricardo interact with each other and Judith's L1 avatar. The avatar directly reconstructs the movements of the real Judith (L0) in VR (see Figure 1). Judith starts the training by performing the first relatively simple posture to be copied by the patients at the hospital in the traditional way and Mireia and Ricardo in the shared space. A representation of the other patients (and/or L3 autonomous characters, which in Phase I will have basic functionality to couple their movements to L1s) will also be seen in the VR space by Mireia and Ricardo. Mireia feels confident about her movement. The melodic sound accompanying her movements and the change in colour of her avatar, from orange to green, informs her that she performed the movement correctly (Phase I – augmented feedback). She feels good! Ricardo is cautious to start moving. During the next repetition, he tries to mimic the posture better and he sees their chosen avatar changing to green and a pleasant chime as he accomplishes the desired posture. When both Judith and Ricardo successfully copy the desired posture, the individual chimes are binding into a more synchronised melody, enhanced visually by a green halo around all the avatars. That way they feel more socially connected with the rest of the group and have a sense of achievement for reaching the group goal. As the sessions go by, they need fewer repetitions to achieve synchrony with the group, and have the feeling that time flies. It is certainly more fun. They also feel more energy, a sense of self-efficacy, and an improvement in their mood.

L1: Judith, Mireira and Ricardo

L3 : other participants to populate the clinical scene

Phase 2: AR:

The platform adapted to an untethered XR solution, enables Mireia and Ricardo to use their XR headsets at home. They enjoy the confidence boost coming from being able to do their exercises as a part of the outpatient community of the Rehab Unit of the Vall d'Hebron hospital. They now have a personalised training programme, enjoying the variety of movements proposed by their therapist Luna. Luna is a L3 avatar, which unlike a human, has unlimited attentional resources to devote to each outpatient at the same time. Another innovation of the second phase of the SHARESPACE programme is that now outpatients can participate in the training with enabled L2 avatars. Unlike L1 avatars, L2 avatars are designed to support their motivation and assist in reward-rich learning of new exercises. L2 avatars amplify the selected movement features, so that in shared space during virtual session, everyone performs the task at least as well as group average, which creates a greater feeling of synchrony and social connectedness between the group members.

Exercises are challenging, but they feel safe about pushing themselves out of their usual comfort zone and enjoying the fluid sense of belonging coming from being in synchronisation with others. Luna provides exercises chosen from a library according to the outpatients' progress which is being monitored across successive sessions. Luna picks up exercises for each of them to maximize a 'rehabilitation index' defined as a function of the outpatients' movement kinematics and other factors indicated by their human therapist (Judith). To feel completely at ease, the actual home setting of the outpatient is not visible to the other Participants or the therapist. Avatars and Luna will be rendered in the safe domestic space chosen by each Participant, in a miniature depiction (to make them feel less imposing, or threatening to their personal, domestic space). They can also choose to render shared space in a neutral, virtual setting (i.e., imagery of an Alpine meadow or Mediterranean beach). If one of the participants cannot make it to the session that day, they can be simulated in real time as an L3 avatar to keep the same numbers in the group.

L2: Mireira and Ricardo
L3: Luna

Partners involved in the health scenario:
DFKI – UM – CRDC – ALE - UJI – GOLAEM – CYENS – DMU – VHRI (lead).

3.2 DELIVERY TIMELINE -> PHASE I (VR)

Table (2) below illustrates the current delivery timeline.

Table 2 Timeline in a healthcare scenario deployment

HEALTH	Task	Partner in charge	STATUS
2023			
01-Jul	UJI and VHIR select the exercises	UJI - VHIR	achieved
08-Jul	UJI-VHIR upload videos of exercises in sharepoint folder (so we can look at them)	UJI - VHIR	achieved
15-Jul	DFKI does the exercises with the sensors to find good location for the sensors, number of sensors	DFKI	achieved
12-Aug	DFKI sends mocap data to CRDC for training	DFKI/CdRC	achieved
16-Sep	SHARESPACE v0.2		achieved
07-Oct	Representative exercises were recorded as videos and shared on the repository	VHIR	achieved
14-Oct	DFKI ran trials with differen people & repetitions to have representative « ranges of motion »	DFKI	achieved
21-Oct	Ethical approval submission	VHIR, UJI	achieved
11-Nov	Data are used by CRDC to refine architecture (for synchronsiation), by CYENS/GOLAEM to prepare rendering, by DFKI to verify sensors location, avatar integration CRDC synchronisaiton	CDRC, CYENS/GOLAEM, DFKI, UM	achieved
16-Dec	SHARESPACE v0.3	DKFI, ALCATEL	achieved
2024			
18-Feb	Trial setup of the VR Phase computers - HMD, computers, architecture // collect some data, add variability to the dataset at DFKI, rfefine location sesnors	VHIR, UJI, DFKI, CYENS	pending
26-Mar	SHARESPACE v1 - beta		pending
18-Jun	SHARESPACE v1		pending
30-Jul	Evaluation Phase I		pending
06-Aug	WORLD PAIN CONFERENCE AMSTERDAM 5-9 AUGUST		pending

3.3 PROTOTYPE DEVELOPMENT ACTIVITIES – EXERCISES OF THE PHYSIOTHERAPY SESSIONS

These exercises are part of standard clinical practice. They are the ones that patients will perform with VR and the telerehabilitation platform. There are 8 exercises with 10 repetitions each. In all VR sessions, they will follow the synchronous indications of the professional.

A total of 10 patients will participate in the validation study (phase 1), Two of them will use the VR setup at the same time (plus the therapist). The two patients using the virtual reality equipment will be in separate rooms in the hospital, while the physiotherapist will be in another room (see Figure 3, 4 and 5). The other patients in the VR group sessions will be L3 avatars. The sessions will last 45 minutes. Below is a description of the exercises with quantitative metrics which were identified by therapists as key to meaningful exercise.

Exercise 1: IN SEDESTATION: breathing exercises with pelvic scale: the patient will be taught to direct the air in inspiration in the abdominal, costal and upper thorax region. Subsequently, the patient will be taught to do the retroversion and anteversion of the pelvis.

For this first part the only way to see if the execution of the movement is right is to check that the place where you put your hands is moving.

For the second part there should be movement in the abdomen towards anterior for inspiration while the pelvis performs a pelvic anteversion of about 30º and then, in retroversion, the abdomen goes to the back and the pelvis rotates about 15º.

The exercise performance is considered good when it is performed about 15º of anteversion and 10º of retroversion.

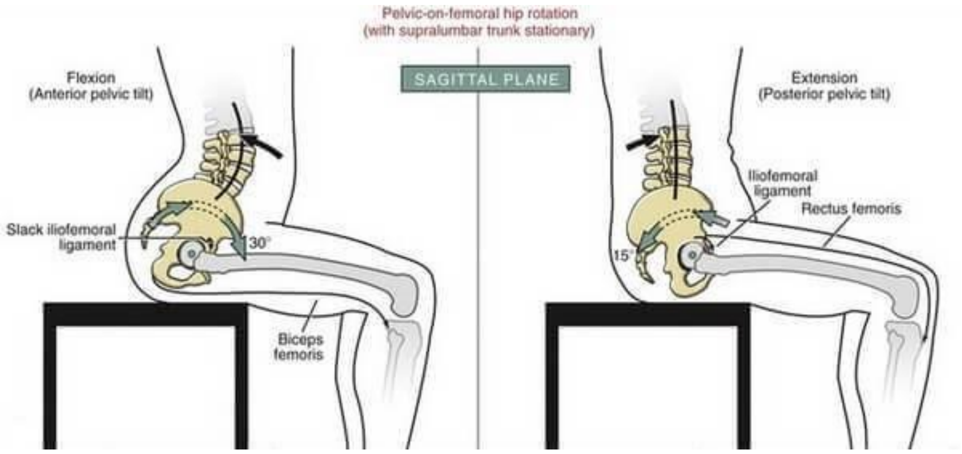

Figure 1. Illustration of Exercise 1.

Exercise 2: IN SUPINE DECUBITUM: Core exercise with the elevation of legs bent at 90º without heel support. Alternating legs. With the patient stretched out on a flat surface in the supine position, raise the right leg so that it rests against the wall. The left leg will pass over the wall, and with both hands, the left leg will be traced from the knee exerting pressure towards the chest. Then we will change the position of the legs to do it five times with each leg.

In the first step, we need movement of the abdomen to the front and then, movement towards the back of the abdomen but without changing the physiological lordosis that would be about 50º.

Performance is considered as good when the degrees of flexion of the coxofemoral are 90º and the degrees of the femorotibial are 90º. The lordosis grades should be maintained at 50º.

Exercise 3: SUPINE DECUBITUM: With the patient stretched out on a flat surface in the supine decubitus position, raise the right leg so that it rests against the wall. The left leg will pass over this, and with both hands, the left leg will be traced from the knee exerting pressure towards the chest, then we will change the position of the legs to do it five times with each leg.

The performance is considered as good when for the starting position, the leg is supported on the wall at 90º of coxofemoral flexion and 90º of femorotibial flexion, while the other leg is at about 30º of flexion and 45º of coxofemoral abdocution and about 100º of the femorotibial flexion. Then the knee approaches the midline of the body between 10-20º.

Exercise 4: SUPINE DECUBITUM: gluteal bridge. The patient will lie on a flat surface in the supine position, with the legs raised, resting completely on the feet. The back will be completely supported on the surface, and the patient will raise his trunk towards the ceiling, taking his back off the floor little by little and returning to his initial position after 5 seconds.

Performance is considered good when the start position is at 45º of coxofemoral flexion and reaches 0º while maintaining a neutral position of the pelvis at 0º as well.

Exercise 5: LATERAL DECUBIT: heels aligned on the midline, knees bent. The patient must stabilize the lumbar spine and then separate the contralateral leg, facing upwards, keeping the pelvis stable.

Performance is considered good when the start position is set at the coxofemoral flexion of 45º, 90º femorotibial the pelvis in a neutral position, and the knees remain in a straight line towards the hips. Pelvis remains in its neutral position and the hip performs a 30º abduction movement.

Exercise 6: BIPEDESTATION AGAINST THE WALL: The patient will stand facing a wall, at a distance equal to the length of his upper limbs in extension and legs apart hip-width apart and in front of each other. Stabilize the pelvis. He leans slightly on his arms, flexing them and letting his weight fall forward, bringing his head close to the wall, holding this position for 5 seconds. Then stretch one leg backwards, with the heel supported, and the other leg bent forwards, stretching the posterior chain for 10 seconds.

Performance is considered good when in the start position person is standing with the glenohumeral joint flexed at 90º and the humerocubital joint at 0º. During the exercise, the glenohumeral joint is abducted 45º and the humerocubital is flexed at 50º. The midline of the body approaches 20 cm towards the wall.

In the second exercise, the leg positioned forward is at 20º of coxofemoral flexion and 30º of femorotibial flexion, and the back leg is positioned at 45º of coxofemoral extension and 0º of femorotibial. (the heels should be touching the floor). During the exercise, the midline body approaches 20 cm towards the wall. With this movement, degrees are gained in the femorotibial of the leg that is forward reaching from 30-50º and in the coxofemoral of the leg that is behind reaching from 45-55º. Pelvis should stay neutral.

Exercise 7: BIPEDESTATION, WALL SITTING: the patient will stand up, leaning his back against a wall. He/she will perform a small leg flexion, going down the wall and stabilizing the pelvis and raising the arms with flexion at 90º on the wall for 5 seconds. Then return to the starting position.

Performance is considered good when the patient is left with a temorotibial extension between 70-90º, a coxifemoral flexion between 20-50º and a glemohumeral flexion of 90º.

Exercise 8: BIPEDESTATION: stretching of the posterior chain + neurodynamics: place the heel of the right leg in front of the body and the left leg backwards. We do anteversion of the pelvis with stretching of the posterior chain and elevation of the arms above the head to produce the whole stretch. Hold for ten seconds and repeat five times on each side.

Performance is considered good when the person performs a pelvic anteversion of 20º, a coxofemoral flexion of the forward leg of 45º with femorotivial at 0º and a tibioastragalina dorsal flexion of 10º. The other leg at 30º of coxofemoral flexion and 30º of femorotibial. In the forward leg the heel is only supported to the floor and the other leg is supported with the whole sole of the food.

In the second part of the exercise, we start from the same position as before with the only modification that the arms are relaxed and the tibioastragalina at 0º of the forward leg, which will be the one that will move. In the realization we notice that while a dorsal flexion of the tibiotalar 10º of the left, a cervical extension of between 20 to 30º is expected.

Figure 2. Exercise 4: SUPINE DECUBITUM: gluteal bridge presented by the medical staff at VHIR.

3.4 ON-SITE SETUP

The hardware will consist of:

- Three Virtual Reality Headsets (Meta Quest Pro)
- Three associated laptops. The connection between the headsets and the laptop is over a cable since the wireless option of headsets is still too limited
- A set of five xDot Movella sensors used for lower body tracking. Those are placed onto each leg segment and the pelvis. They are connected with Bluetooth to the system.
- A server and a router for the local network and Rainbow software, which will connect the three laptops with minimal data transmission delay. Ideally, the server runs on one of the laptops so that no additional hardware is necessary. This configuration and its limits are currently being tested by the partner ALE and will be confirmed by the beginning of February.

Further functional and non-functional requirements can be found in the previous deliverable D1.2. Research Requirements for challenges and scenarios v1. Considerations for avatar design were previously addressed in D4.1: SHARESPACE avatar definition v1.

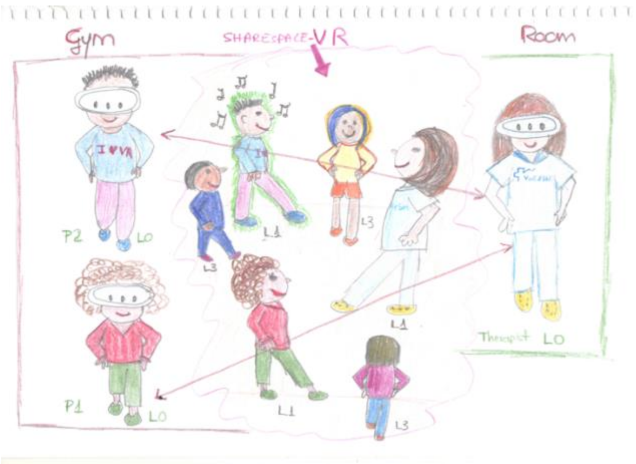

Figure 3. Illustration of Phase I setup of two participants being and therapist partaking as L1s.

3.5 RENDERING SPECIFICATION

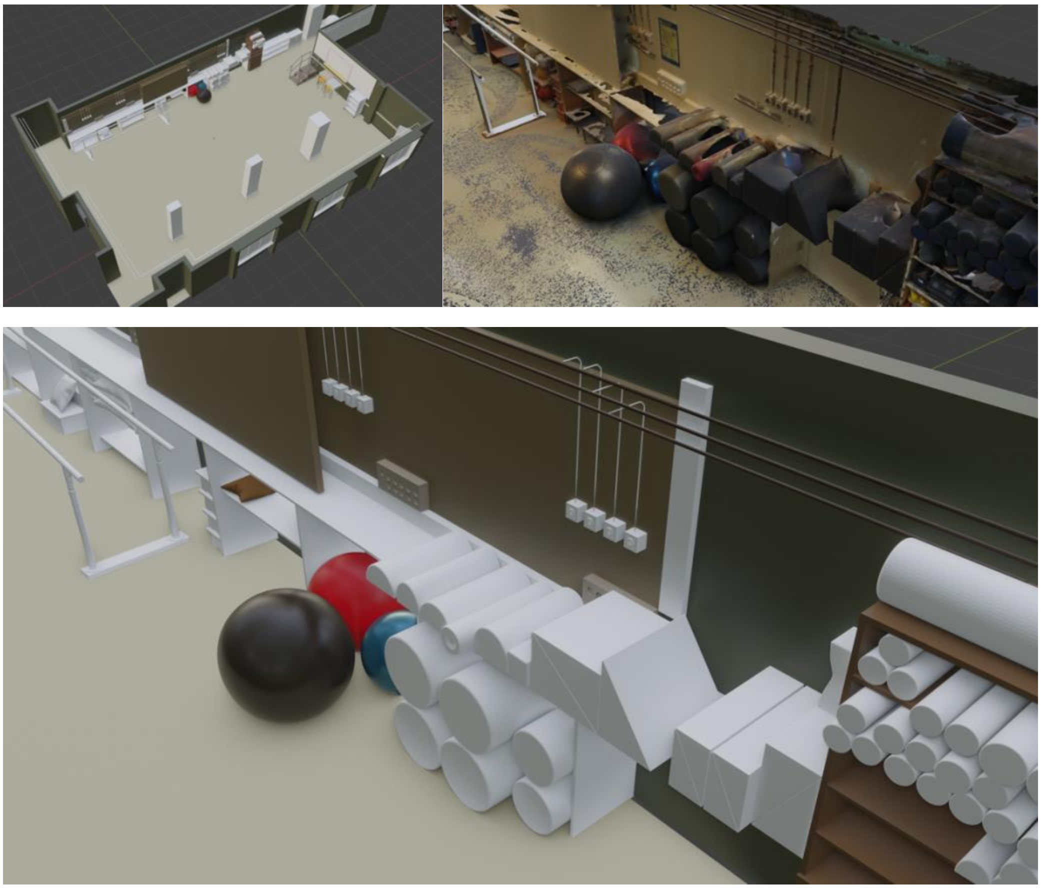

Figure 4. Screenshots of the Work-in-progress 3D model of the hospital room at VHIR that patients are familiar with. The entire room (top left) was initially scanned (top-right) using a laser scanner and then remodeled to be appropriate for use in VR (bottom). The 3D model will next be textured to be as close as possible to the original environment.

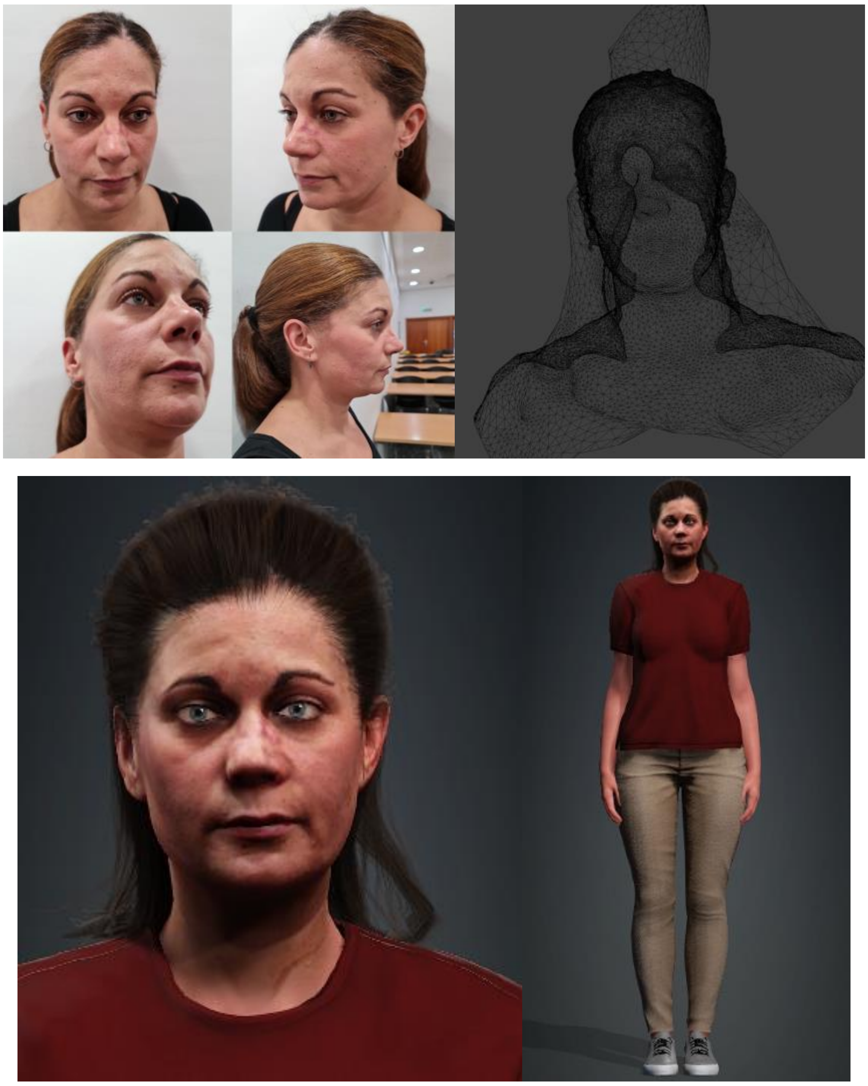

Figure 5. 3D Avatar of the therapist.

Figure 5 illustrates the Avatar of the therapist. It was created by first taking a set of several images of the head of the therapist, and then using these to create a mesh of the head. Then, this was imported into Character Creator by Reallusion to add on a body and rig; hair was added from a collection and was not reconstructed. This rig can then be animated using both motion capture data (body) and audio (face).

3.6 METRICS

- **Brief Pain Inventory Short Form** (BPI, Cleeland & Ryan, 1994) https://pubmed.ncbi.nlm.nih.gov/8080219/ severity of pain and its impact on functioning
- **The Tampa Scale of Kinesiophobia** (TSK, Miller, Kori & Todd, 1991). https://journals.lww.com/clinicalpain/Citation/1991/03000/The_Tampa_Scale__a_Measure_of_Kinisophobia.53.aspx pain-related fear of movement
- **5-level EQ-5D version** (EQ-5D-5L, Herdman et al., 2011) https://doi.org/10.1007/s11136-011-9903-x health-related quality of life
- **Profile of Mood States** (POMS-2A, Heuchert & McNair, 2012) Heuchert, J. P. & McNair, D. M. (2012) Profile of Mood States 2. Multi-Health Systems (MHS), Toronto, ON affect states. Six dimensions: anger-hostility; confusion-bewilderment; depression-dejection; fatigue-inertia; tension-anxiety; vigour-activity
- **The Oswestry Disability Index** (ODI, Fairbank & Pynsent, 2000) https://doi.org/10.1097/00007632-200011150-00017 low back pain disability
- **System Usability Scale** (Brooke, 1996).
  Brooke, J. (1996). SUS: a "quick and dirty" usability scale. In B. A. In P.W.Jordan, B. Thomas & and I. L. M. Weerdmeester (Eds.), Usability Evaluation in Industry (pp. 189–194). Taylor and Francis. Easy of use, intention of use
- **Virtual Embodiment Questionnaire** (Roth & Latoschik, 2020).
  https://doi.org/10.1109/TVCG.2020.3023603
  perceptual aspects of embodiment: ownership, agency, change.
- **Virtual Human Interaction Lab Presence Scale** (Han, Miller, Ram, Novak & Bailenson, 2022)
  https://vhil.stanford.edu/ social presence, self-presence, and spatial presence.
- **Technostress Creator Stress** (TCS, Ragu-Nathan et al., 2008)
  DOI:10.1287/isre.1070.0165 techno-overload (increased workload); techno invasion (work-home conflict); techno-complexity (feeling of inadequacy due the complexity of the ICT and spending time and effort to learn and understand

them); techno-insecurity (feeling threatened by the ICT); techno-uncertainty (constant changes associated to technologies

- **Simulator Sickness Questionnaire** (SSQ, Kennedy et al., 1996). doi: 10.1207/s15327108ijap0303_3 occurrence of 16 symptoms classified in three categories: oculomotor, disorientation, and nausea due to the VR experience
- **Intrinsic motivation scale** - Elliot and Harackiewicz's (1996) https://doi.org/10.1037/0022-3514.70.3.461 intrinsic motivation
- **Basic Needs Satisfaction in Sport Scale** - Ng et al.'s (2011) relatedness scale of the a measure of basic needs satisfaction in sport (autonomy, competence, and relatedness). doi.org:10.1016/j.psychsport.2010.10.006
- **Approach-Avoidance System Questionnaire** - Teboul et al.'s (2019) doi: 10.3389/fpsyg.2019.02531. Competence expectancies (e.g., For the next session, I feel up to the task), benefit for the self (e.g., If I succeeded in the task of the coming session, I would be proud of myself), and threat for the self.

Physical measures – metrics:

- Number of repetitions
- Movement amplitude for segments of interests
- Movement frequency/speed
- Group synchronisation (not sure if possible depends on the task).

3.7 KPIs

The most important achievement if the SHARESPACE health scenario is feasible, acceptable and effective is that this could make a significant contribution to improving access to rehabilitation intervention for chronic pain patients, reducing waiting lists and reducing the time and cost of the intervention (being able to conduct rehabilitation sessions at home, reducing financial costs of trips, reducing travel time to the hospital, and reducing time of therapist).

Another important achievement will be to be able to personalize the intervention based on a more accurate capturing of the movement data and more accurate feedback. And all this in a social virtual environment, that is, gaining in personalization without losing the group effect.

One important contribution of SHARESPACE compared to the use of other technologies (for example, online video rehabilitation) is that the technology (remote VR and AR) will simulate group sessions. The participants will perform the rehabilitation exercises with other participants (also avatars) in a shared space, promoting **social presence** and **social connectedness**. In addition to the social presence effect, the VR scenarios will provide feedback to both patients and the therapist about the performance of the rehabilitation exercises, contributing to more accurate monitoring of the patient's progress.

In Phase 1 a usability study will be conducted:

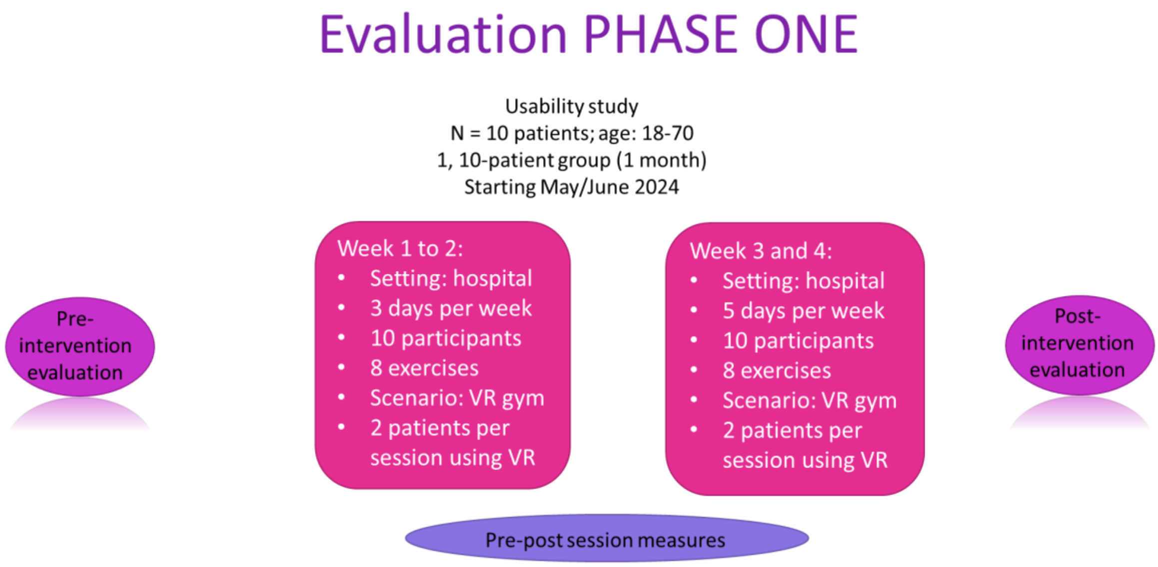

Figure 6. Breakdown of KPIs for the Phase I VR

The metrics will evaluate the key outcomes related to usability, feasibility, acceptance and motivation (System Usability Scale, Intrinsic Motivation Scale, Basic Needs Satisfaction, Approach-Avoidance System Questionnaire). The metrics also include specific assessment of variables related to making the experience meaningful from a personal and social point of view (Virtual Embodiment Questionnaire, Virtual Human-

Interaction lab presence Scale). Possible negative effects will also be measured (Technostress Creator Test, Simulator Sickness questionnaire). Finally, although the main outcomes are usability and feasibility, preliminary effectiveness will be measured by pain-related measures (BPI, TSK, EQ-5D-5, POMS-2A, and ODI).

Tech SHARESPACE concept validity evaluation:

SHARESPACE technology aims to create embodied**, hybrid spaces**, which will allow to reconstruct and map the core sensorimotor primitives to L1-L2 avatars (see D2.1 Explanation on the information encoding and library of sensorimotor primitives v1). This process is key for a new level of immersion and embodiment in MR spaces. Therefore, it is essential to assess the read-out and perception of movement rendered for L1-L3 avatars, from the angle of realism, and information encoded. To address this point iterative design approach will be practiced to conduct thorough testing with pilot and feasibility study users to identify any discrepancies between input and virtual representations.

Transmission of information encoded in sensorimotor primitives will also be assessed in PoP Social Sync and Chinese Whispers, dedicated to the identification of information encoding and readout, and propagation paths across different users.

Scenarios discussed in this deliverable D6.1 – will be a source of immediate feedback will be gathered and core SYSTEM ARCHITECTURE team will iterate on the system to address issues related to input-source correlation. Consistency in input of source data and output rendered representation is one of the key objectives to be assessed in the real-world deployment of his scenario (full body motion and clear physical designates for exercise). If needed, observational study protocols will be deployed where SHARESPACE researchers observe users interacting with the VR system. This can provide insights into the naturalness and intuitiveness of the sensorimotor primitives mapping. In addition, approaches such as Learnability and Adaption might prove useful to evaluate how quickly users learn to use the input devices and adapt to the mapping. A well-designed mapping should facilitate a short learning curve. Finally, assessments of mental demand, physical demand, and frustration can provide insights into the usability of the input mapping (such as NASA-TLX).

Usability evaluation:

Given the sensitive nature of this feasibility, in addition we will assess the following parameters by reports collected at the piloting stage and after each session to monitor the impact of the SHARESPACE system on the users.

- **Task Success Rate:** Percentage of completed tasks.
- **Error Rate:** Frequency and severity of user errors during tasks.
- **Time on Task:** Amount of time users take to complete specific tasks.
- **Learnability:** Speed at which users can learn to navigate and operate the system.
- **User Satisfaction:** Overall satisfaction with the medical system.
- **Usability Issues:** Identification and categorization of encountered usability problems.
- **Task Completion Time Variability:** Consistency in task completion times among users.
- **Effectiveness in Critical Tasks:** Performance in tasks crucial for patient care.
- **Error Severity:** Categorization of severity for user errors.
- **Accessibility:** Evaluation of system accessibility for diverse user needs.

3.8 OPEN EVENT DESCRIPTION 2024

A symposium proposal has been submitted to the 2024 World Congress on Pain, the most important conference on the scientific research and clinical practice related to Pain organized by the International Association for the Study of Pain. The conference will be held in Amsterdam August 5th to 9th 2024. https://www.iasp-pain.org/iasp-2024-world-congress-on-pain/

Title: Embodied Social Experiences in Hybrid Shared Spaces to support rehabilitation in chronic low back pain. The SHARESPACE project.

Summary: We present the foundations of a hybrid, multimodal-multisensory platform that supports physical rehabilitation in low back pain. It has been developed within the SHARESPACE Horizon Europe project www.sharespace.eu. Our goal is the creation of Social Hybrid Spaces shared by humans and avatars engaged in embodied collaborative tasks, and here we test our solution in a Social Pain Exergame. SHARESPACE aims to address important challenges like access to interventions and more personalized treatments in chronic pain care. Since physical therapy lessons have the downsides of being at a fixed time or far away from the patients' home, this mixed reality application might be a solution for reducing waiting lists, assessing progress more accurately, and personalizing the intervention allowing patients to follow physical therapy in a Shared Hybrid Space from the comfort of their homes. The symposium will include four presentations:

1. The SHARESPACE unified and operational framework
2. Demonstration of the SHARESPACE eXtended Reality platform
3. Demonstration of the SHARESPACE application in chronic low back pain
4. Feasibility of the use of an eXtended Reality platform to support physical rehabilitation

We expect to have a response about the acceptance of the Symposium in March 2024.

3.9 RISK MITIGATION

As specified in the Deliverable 8.1 we have identified a list of risk that might emerge during the deployment of the Health Scenario across Phase I and Phase II and we list them in Table 3.

Table 3 Breakdown of identified risks and mitigation strategies for Social Lower Back Scenario

Risk ID	Description of risk	Likelihood	Severity	Status	Responsible Partners	Proposed risk-mitigation measures
6.1	Very ambitious real-world scenarios, which cannot be implemented properly, hindering a correct validation of the approach	Medium	High	Prevention	UM	Several measures have been taken in order to minimise this risk: (1) Mi-term integration and validation at M20; (2) substantial involvement of all partners in WP6; (3) Early start of trial preparation, M5 and integration, M10.
6.2	Temporal mis-alignment of evaluations and demos with international events (e.g., Paris2024) due to project's start and delays	Medium	Medium	Prevention	UM	Demonstration of available integrated technological bricks at these highly visible events. Evaluation periods (phase 1 and 2 for 3 scenarios) partly decoupled from events.
6.3	Low acceptability of hardware devices by patients.	Possible	High	Prevention	VHIR/UJI/DFKI/UM	Testing of hardware with patients during development: patients at the hospital and members of user advisory board. Inclusion of acceptability measures in the pre-validation and validation phases.

6.4	Fatigue in patients while using VR/AR devices.	Probable	Medium	Redressing	VHIR/UJI/DFKI/UM	Testing of hardware with patients during development: patients at the hospital and members of user advisory board. Programming of sessions including breaks.
6.5	Low acceptability of VR/AR use from health professionals.	Possible	Medium	Redressing	VHIR/UJI/DFKI/UM	Inclusion of health professionals in user advisory board to get feedback during development.
6.6	Access to patients willing to participate in testing of the scenario.	Not likely	Low	Prevention	VHIR/UJI/DFKI/UM	VHIR partner is a hospital with pain and rehab units with easy access to patients
6.7	Difficulty of performing rehabilitation exercises with VR/AR devices.	Possible	Medium	Redressing	VHIR/UJI/DFKI/UM	Selection of exercises balancing clinical efficacy and easiness to perform with VR/AR devices (testing with patients during development)
6.8	Difficulty for patients to use VR/AR equipment at home.	Possible	High	Redressin	VHIR/UJI/DFKI/UM	Performing VR/AR sessions first at hospital for training. At least first VR/AR session with research assistant.
6.9	Low social presence and other social indicators) during VR/AR sessions.	Possible	High	Prevention	VHIR/UJI/DFKI/UM	Testing of different types of avatars, L1, L2, L3 and their influence in social indicators. Testing of different amplification cues and their influence in social indicators. Inclusion of social presence measures in the pre validation and validation phases.

6.10	Rejection from patients of using VR/AR at home for fear of privacy breach.	Possible	High	Prevention	VHIR/UJI/DFKI/UM	The data transmitted to the hospital are only movement primitives and on request a live video stream for video conferencing. The functionality of blurring the background should be provided. The data transmitted to the hospital are only movement primitives and on request a live video stream for video conferencing.

4 SHARESPACE FOR SPORT

4.1 SCENARIO DESCRIPTION

The scenario is focused on PERFORMANCE, when expert cyclists face "opportunities of attack" in a peloton.

Partners involved in the sport scenario: DFKI - UM- ALE – RICOH- CRDC- UKE - GOLAEM-DMU - INRIA (lead). The updated description of the scenario (in comparison to the proposal description) is below.

Phase I (VR): Mathieu, Anne, John, and Emma, four experienced cyclists, are at home with their own bikes mounted on Wahoo KickR (home trainer device). Their objective is to enhance their peloton riding skills and train for future races by learning how to detect (i) when to initiate an attack while in a breakaway and (ii) when a partner is about to launch an attack to follow him promptly. They are all wearing VR glasses and are immersed in a virtual environment. Sara, an autonomous character, serves as an opponent in this training session, leading the peloton. The peloton rides on a virtual road at high speed, mimicking the conditions of cycling races, but without traffic. Sara (L3) takes the lead in the group, with Mathieu, Anne, John, and Emma following her. Mathieu, Anne, John, and Emma belong to the same team, and are supposed to help Anne to win the race. As the slope becomes steeper, Sara exhibits signs of fatigue, which are supposed to be detectable by Mathieu. Mathieu is instructed to initiate an attack as soon as he detects those signs. The idea is to attack with the aim to allow Anne, John and Emma to follow him and benefit from the “pull” effect due to air friction. When initiating the attack, Mathieu exhibits some signs associated with the preparation of the change of direction and increase in speed. These signs should be minimized by Mathieu to conceal from opponents this intention to attack, but they should be visible for Anne, Jon and Emma to encourage them to follow him rapidly. Hence, in VR, the specific variables associated with Mathieu’s attack preparation are amplified at early stages of the attack (Mathieu’s avatar is L2, driven by the cognitive architecture) for Anne, John and Emma. Hence, this amplification enables Anne to more easily detect and follow Mathieu's move as soon as she can and benefit from this “pull” effect. When Anne accelerates, John and Emma have to follow her. Their avatars are L1. The cognitive architecture enables amplification of Mathieu’s L2 movements to make visible to the followers the relevant anticipatory variables. In a long-term training perspective, amplification can be adjusted: from large modification at the beginning of the training process, to little or no amplification at the end of this training sessions.

In summary, we have the following individuals:

- **L0:** Mathieu (MA), Anne (AN), John (JO), Emma (EM)
- **L1:** L1AN, L1JO, L1EM (avatars representing Anne, John, and Emma)
- **L2:** L2MA (amplified avatar of Mathieu to facilitate perception by Anne, John, and Emma)
- **L3:** Sara (SA)

Phase II (XR): The aim of the second phase (XR) is to use the skills acquired in the first phase (VR) in a more realistic race environment. In a preliminary offline stage, Mathieu has integrated a set of 360° cameras on his bicycle. He uses these cameras to generate a 3D model of the terrain that will be integrated into a navigable virtual environment that he can share with other participants. These participants can load this virtual environment in their SHARESPACE peloton XR equipment (Phase I: VR). After this offline process, Mathieu returned to the road with his bike and SHARESPACE peloton XR (Phase II: AR) equipment. The other invited participants join him remotely to replay the same attack scenario than previously (detecting and following an attack) on his favorite route modeled in the shared virtual environment, using their SHARESPACE peloton XR equipment (Phase I: VR). Using embedded cameras, sensors, and GPS positioning, Mathieu's position is tracked within the navigable model to ensure colocalization in the real and virtual environment. This allows his avatar to be visible to everyone within their local representation of the terrain. Their virtual opponent Sara remains present throughout this experience, returning to lead the breakaway after each attack phase, and showing again signs of fatigue on some steep slopes, offering her followers the opportunity to create a new attack. In the real world for Mathieu, his gestures during the attack are more realistic than when using home trainer in Phase I: VR. His invited partners can then continue their training session with a real attack of Mathieu in the real world, instead of a simulated one in VR. Each of Mathieu's friends is eager to share their experience on roads near their own homes and begins utilizing the SHARESPACE peloton XR equipment (Phase II: AR).

In summary, again, we have the following individuals:

- **L0:** Mathieu (MA), Anne (AN), John (JO), Emma (EM)
- **L1:** L1AN, L1JO, L1EM (avatars representing Anne, John, and Emma)
- **L2:** L2MA (amplified avatar of Mathieu to facilitate perception by Anne, John, and Emma)
- **L3:** Sara (SA)

4.2 DELIVERY TIMELINE

Table 4 Timeline in a cycling scenario deployment

SPORT	Task	Partner in charge	STATUS
2023			
01-Jul	Definition of system requirements	INRIA	achieved
08-Jul			
15-Jul			
22-Jul	Animation of virtual cyclists with GOLAEM (Animation + bending metaphore)	INRIA, Golaem	achieved
02-Sep	Cyclist turning modelling from ergocycle sensors (handlebar rotation and bending)	INRIA	achieved
09-Sep			
16-Sep	SHARESPACE v0.2	DFKI	pending
23-Sep			
30-Sep			
07-Oct	Identify readout (for amplification - L2)	INRIA, UKE, UNINA	pending
09-Dec			
16-Dec	SHARESPACE v0.3	DFKI	pending
05-Mar			
12-Mar	SHARESPACE v1 beta		pending
30-Apr			
07-May	Evaluation Phase I (VR)	INRIA	
14-May			
18-Jun	SHARESPACE v1		pending
23-Jul	OLYMPIC GAMES 26 JULY - 11 AUGUST (SHARESPACE BOOTH)		
30-Jul	OLYMPIC GAMES 26 JULY - 11 AUGUST (SHARESPACE BOOTH)		
06-Aug	OLYMPIC GAMES 26 JULY - 11 AUGUST (SHARESPACE BOOTH)		
13-Aug	OLYMPIC GAMES 26 JULY - 11 AUGUST (SHARESPACE BOOTH)		

4.3 PROTOTYPE DEVELOPMENT ACTIVITIES

To develop the prototype, the first step is to collect kinematic data in real conditions. To do it, expert cyclists are invited to participate in motion capture sessions, during which they have to perform different cycling movements (e.g. speed variations, taking turns, etc) as well as simulating attacks (in group of 3). To ensure the safety of participants, the experiments are carried out on a karting track. At the time of deliverable, this first step is in progress.

Cyclists wear a Xsens MVN Link suit to record their motion. Some recorded data are illustrated in figure Figure 7. Examples of in-progress motion capture data of real cyclists in real conditions using X-sens MVN Link suits. The bike is equipped with Xsens DOT sensors: one on the frame to record body and bike bending data, one on the wheel to record cycling speed, and one on the handlebar to record its rotations.

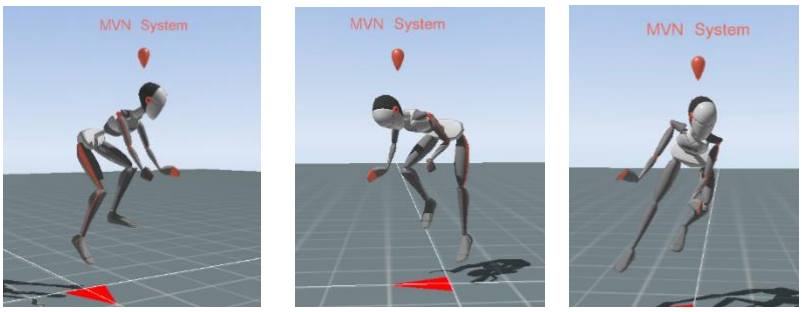

Figure 7. Examples of in-progress motion capture data of real cyclists in real conditions using X-sens MVN Link suits

The collected data will allow the realization of 2 phases of development:

1) The generation of a database of cycling movements, which will be used to realistically animate the avatars.
2) The identification of relevant information (the readout phase), that specify the attack, and that the SHS architecture should amplify or attenuate in the scenario.

The detailed information about the principles of encoding and readout can be found in previous deliverable D2.4: Social information readout and interaction. From there, we can develop the animation method of the cyclist (ask the database with Xsens DOT data to extract the most realistic motion) and refine the rendering aspects.

The last step consists of integration of:

1) The cognitive architecture to amplify or attenuate the relevant kinematic motion.
2) The rainbow network to send the bvh file to Unreal.

Further functional and non-functional requirements can be found in the previous deliverable D1.2. Research Requirements for challenges and scenarios v1. Considerations for avatar design were previously addressed in D4.1: SHARESPACE avatar definition v1.

4.4 ON-SITE SETUP

During the evaluation session, each cyclist will come to the laboratory with their own bike. These bikes will be placed on smart trainers, which have the particularity of benefiting from a Bluetooth communication protocol. This Bluetooth communication makes it possible to retrieve information such as bike speed or power output.

Participants will all be equipped with 8 Xsens DOT sensors to track their movements: 2 feet, 2 hands, pelvis (sacrum), head, saddle and handlebar. Because it is impossible for cyclists to lean on the home trainer the way they do it in the real world, they will use the handlebar to indicate a change of direction. A pre-recorded database of real cyclist motion will then be used to search for the closest motion clip, while considering the global velocity and orientation (to take the inertial forces into account compensated by leaning movements). The actual cyclist's pose and bicycle orientation will be obtained thanks to this process, which will not correspond to the actual motion of the user, due to different physical constraints if avatar environment.

On the machine side, we will have:

- 1 computer for each participant to collect the motion data;
- 1 additional computer for rendering the 3D virtual environment in the HMD. The participants' VR HMD Meta Quest Pro will therefore be linked to it.

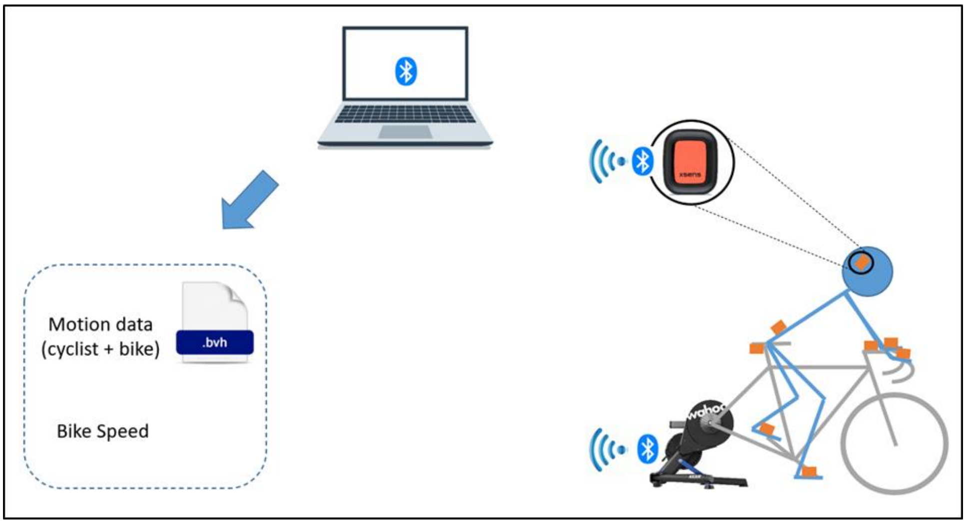

Figure 8. Illustration of the set-up that will be used to collect motion data from a cyclist on smart-trainer and return an associated pose for the avatar.

4.5 RENDERING SPECIFICATION

In the cycling scenario, the appearance of the avatars does not necessarily need to be close to that of the users. Indeed, when riding in a peloton, cyclists only see the other avatars from behind. Also, a user only perceives the leg or arms of his own avatar. For these reasons, users will only have the choice between 2 or 3 avatars (e.g., different morphology or skin color) and will also choose their outfit colors.

Figure 9. The 3D model of cyclist and bike that will be used for the cycling scenario

As explained in part 3.3, we are currently working on creating a database of real cycling motions. When users operate in the virtual environment, this database will be queried with IMU data as inputs. The system will then seek to associate with the IMU data the motion that best corresponds to the situation. As an output from our database, we will obtain an animation file (bvh format) adapted to the morphology of the avatar and its bike. This bvh file containing all joint angles will be sent to the Golaem module that performs the animation in Unreal Engine.

4.6 Scene Capturing and Neural Rendering with Multiple MSI

To capture a scene with images that can be within the cyclist's view, we mount cameras on a rig that is attached to a bicycle. The bicycle will be pushed or ridden through the scene that needs to be captured. Multiple bicycles or multiple tours with a single bicycle will be necessary to capture multiple tracks.

We consider five forward-facing cameras and one back-facing camera (see Figure 10 and Figure 11). The cameras have a large field of view, which helps to capture a large amount of the scene. The forward-facing cameras will ensure that the cyclist will have a good forward view no matter how they move their head. A backward-facing camera is necessary to provide a full 360° field of view.


Figure 10 The camera rig with six cameras attached to a bicycle

A neural network will be trained on the captured images to learn the scene in full or in parts. Multiple MSI can be extracted from neural networks trained on the scene to enable real-time rendering (Figure 12).

Figure 11 An example of an image captured with a camera on the camera rig.

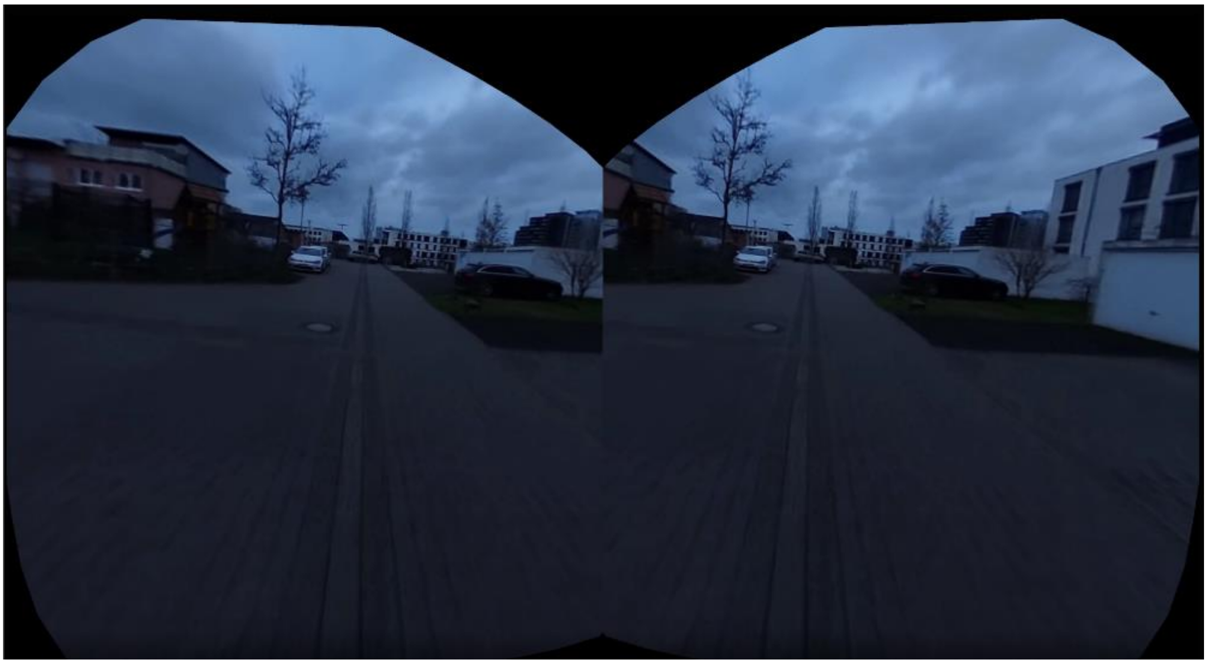

Figure 12 An example rendering of an MSI in VR. Visible are the two views for the left eye and right eye, respectively.

4.7 METRICS

During the experiments, we will use 3 questionnaires to assess Presence, cybersickness and technology acceptance:

- **Slater-Usoh-Steed** (SUS, Usoh 2000) -> to use during experiment
  Schwind et al., 2019 : https://dl.acm.org/doi/10.1145/3290605.3300590 doi : 10.1162/105474600566989 Presence

- **Technology Acceptance Model** (TAM, Venkatesh & Bala 2008)
  https://onlinelibrary.wiley.com/doi/10.1111/j.1540-5915.2008.00192.x
  Perceived ease of use and perceived usefulness of the technology

- **CSQ-VR** (Kourtesis et al., 2022)
  https://www.researchgate.net/publication/366400274_CyberSickness_in_Virtual_Reality_Questionnaire_CSQ-VR_A_brief_tool_for_evaluating_the_Virtual_Reality_Induced_Symptoms_and_Effects_VRISE?channel=doi&linkId=63a053fa024dc52c8a321083&showFulltext=true

Cybersickness : 6 questions to assess three types of cybersickness symptoms (nausea, vestibular and oculomotor)

To measure the performances of the cyclists, we will need to compute the following metrics:

- Start time of the attack;
- Reaction time (i.e, time between the start of the attack and the moment the follower reacts to follow it);
- Speed and power output data before and during the attack;
- Kinematic data and more precisely the values of the variables that characterize the launch of an attack in the animation;
- Distance between the cyclist who launch the attack and the cyclist who needs to follow him.

4.8 KPIs

The Phase I evaluation of the scenario consists of a pre- and post-evaluation of cyclists' performance based on the measurement of its key factors. These factors are global cues such as the cyclist's displacement or speed, but also local cues such as head and body orientation, postural changes or handlebar rotation (cf. measured metrics). The evaluation phase is described in the following figure.

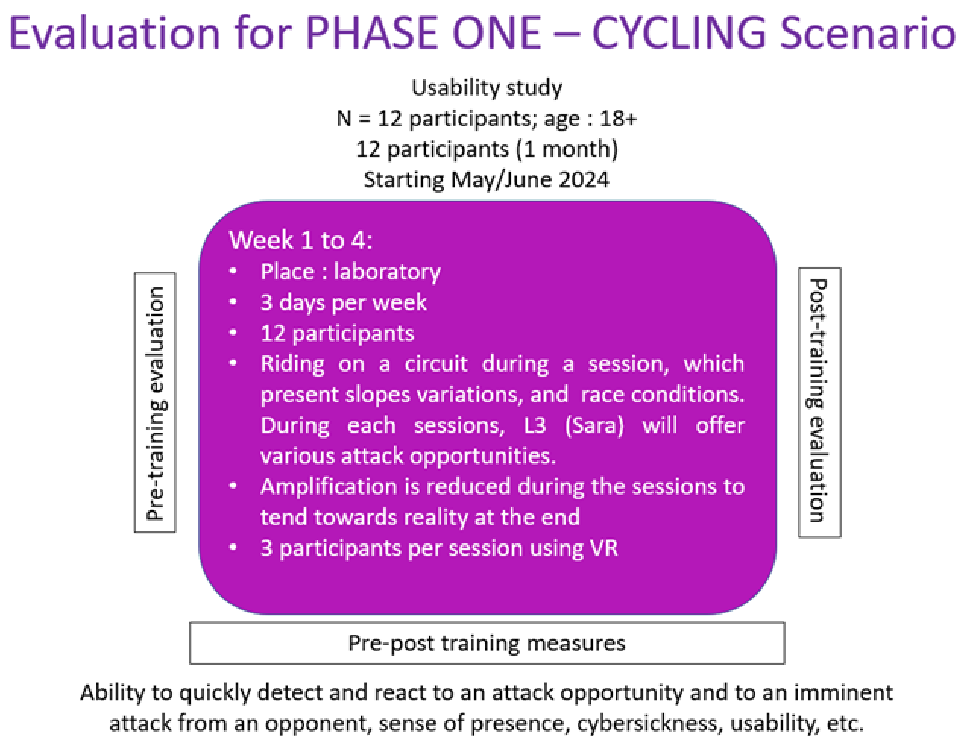

Figure 13. Illustration of the protocol for the phase I evaluation of the cycling scenario

To train the cyclists to learn how to perceive the right information specifying the attack, this information will initially be amplified to a large extent and, over the course of the training sessions, they will be amplified less and less until they return to real values without anticipation. Evaluations of the cyclists' improvement will imply pre-post comparisons of actual performance (without amplification).

4.9 OPEN EVENT DESCRIPTION 2024

The French Ministery of Research is organizing a dedicated scientific event at "C*ité des Sciences et de l'Industrie* in La Villette" during the 2024 Olympic and Paralympic Games in Paris. In this context, INRIA has secured a SHARESPACE booth, with a permanent demo about the cycling scenario. This demo will take place over 3 weeks: from 27th of July to 11th of august for the Olympic Games, and from 29th of august to 8th September for the Paralympic Games.

4.10 RISK MITIGATION

Risk mitigation was addressed in the D8.1, which we recap below in the Table below.

Table 5 Breakdown of identified risks and mitigation strategies for Cycling scenario

Risk ID	Description of risk	Likelihood	Severity	Status	Responsible Partners	Proposed risk-mitigation measures
6.11	Cybersickness caused by the discovery of new sensory-motor relations (VR is not usual for most individuals)	Possible	High	Prevention	INRIA/UM	Insert a substantial familiarization period. Avoid sharp turns at high speed (and possibly moderate speed) which can be very disturbing, even with practice. Inclusion of cybersickness measures in the pre validation and validation phases.
6.12	Cybersickness caused by HMD device and more specifically related to the delay between the head movement and display update	Possible	High	Prevention	INRIA/UM	Select the right HMD with optimal refresh rate to have an acceptable delay between image update and head movements. Inclusion of cybersickness measures in the pre validation and validation phases.
6.13	Eyestrain caused by the HMD device	Possible	Medium	Prevention	INRIA/UM	Limit session time to be acceptable

6.14	Fall off the bike in VR:	Low	High	Prevention	INRIA/UM	Avoid sharp turns at high speed (and possibly moderate speed) to prevent the user from wanting to tilt too much. When we ride a bike in the real world, we lean when we turn. This inclination depends on the radius of curvature of the turn and the speed of the bicycle. Users well immersed in the virtual environment will tend to tilt the bike as in the real world to turn. However, the home trainer having a very limited degree of lateral freedom to prevent the bicyle to fall. However, this can surprise the user who can lean his body excessively and fall off the bike. Pay attention to the home trainer stability: - For basic set-up: the home-trainer should be placed on a flat surface, in its most stable configuration. - For a set-up using a platform allowing tilting: the platform should be placed on a flat surface and the home-trainer should be well fixed to the platform in its most stable configuration. Solution: The system has to be safeguarded not to tip to the side. If any real risk or discomfort is identified when using a tilting platform, we will not use this approach anymore.

6.15	AR: Accident, due to traffic (e.g., other bicycles, cars, pedestrians, etc...) or presence of obstacles (e.g., rock, barrier, etc...).	Low	High	Prevention	INRIA/UM	If this risk is present in real life, it is increased by using AR technology. Indeed, the virtual elements that will appear in the field of vision of the user can mask the dangers of the real world (e.g. a virtual avatar can mask a real rock or car in the field of vision of the cyclist). Solution: Stay on bike paths and safe roads, with no traffic and no obstacles. The proof of concept of this work will be performed on Karting or racing car circuits with no other participants to ensure security. We will also evaluate the potential risks If this system is transferred to real world conditions.

5 SHARESPACE FOR ART

5.1 SCENARIO DESCRIPTION

The art scenario within SHARESPACE has the goal of exploring the possibilities of SHARESPACE technology through a bottom-up fashion. In the scenario, multiple artworks will be created for the Deep Space 8K, located at the Ars Electronica Center in Linz, and presented during the Ars Electronica Festivals 2024 & 2025. Deep Space 8K (please see Figure 14) enables immersive XR environments through 3D stereoscopic wall and floor projections (both 16m x 9m). Artworks shown in Deep Space 8K can be made interactive by its laser tracking system PHARUS, which enables the system to determine the 2D position of objects on the floor. Within this scenario, the participating artists are invited to create a multi-user, hybrid, interactive art performance that leverages embodied interaction between people, different types of Virtual Humans, and SHARESPACE concepts and technologies. The artworks will be developed by SHARESPACE partner Ars Electronica Futurelab, and by external artists that are recruited through an Open Call.

Figure 14. Deep Space 8K, "Cooperative Aesthetic - Color Bars" by Gerhard Funk (AT), Credit: Ars Electronica

Artistic Exploration

The realization of the artworks requires an integration of the existing Deep Space 8K infrastructure and the novel SHARESPACE technology. This is done through the development of a SHARESPACE plug-in for Unreal Engine. That way, artists can develop their artworks in Unreal Engine with the security that it can then be rendered in the Deep Space environment. Considering it is the responsibility of the Ars Electronica Futurelab team to develop this plug-in, and it is vital to build up tacit knowledge with the SHARESPACE technology to support the external artists, their internal artwork will be developed first. So far, the Futurelab team has been working on the development of two concepts (both working titles): Falcon Heavy and Convergence.

Falcon Heavy

Falcon Heavy is a shared multi-user experience for Deep Space. As a real-time, generative artwork it becomes a stereoscopic A-V sculpture in flux; a living and ever shifting entity within a semi virtual arena populated by onsite- as well as offsite-users participating together. The living sculpture is situated within a twofold arena, one side as physical (deep) space, and the other side as virtual (deep) space. The wall projection area acts as a bounding surface in between. The movements of participants are tracked and represented vice versa in both deep spaces (virtual/physical). The ever-shifting entity can be bound into concrete/discrete forms (gestalt) if participants move into certain constellations or spatial configurations (imposed dramaturgy, performance, structure). Synchronization plays a key role in this exploration as participants constantly fall in and out of sync with each other whilst interacting with the ever-evolving real time sculpture.

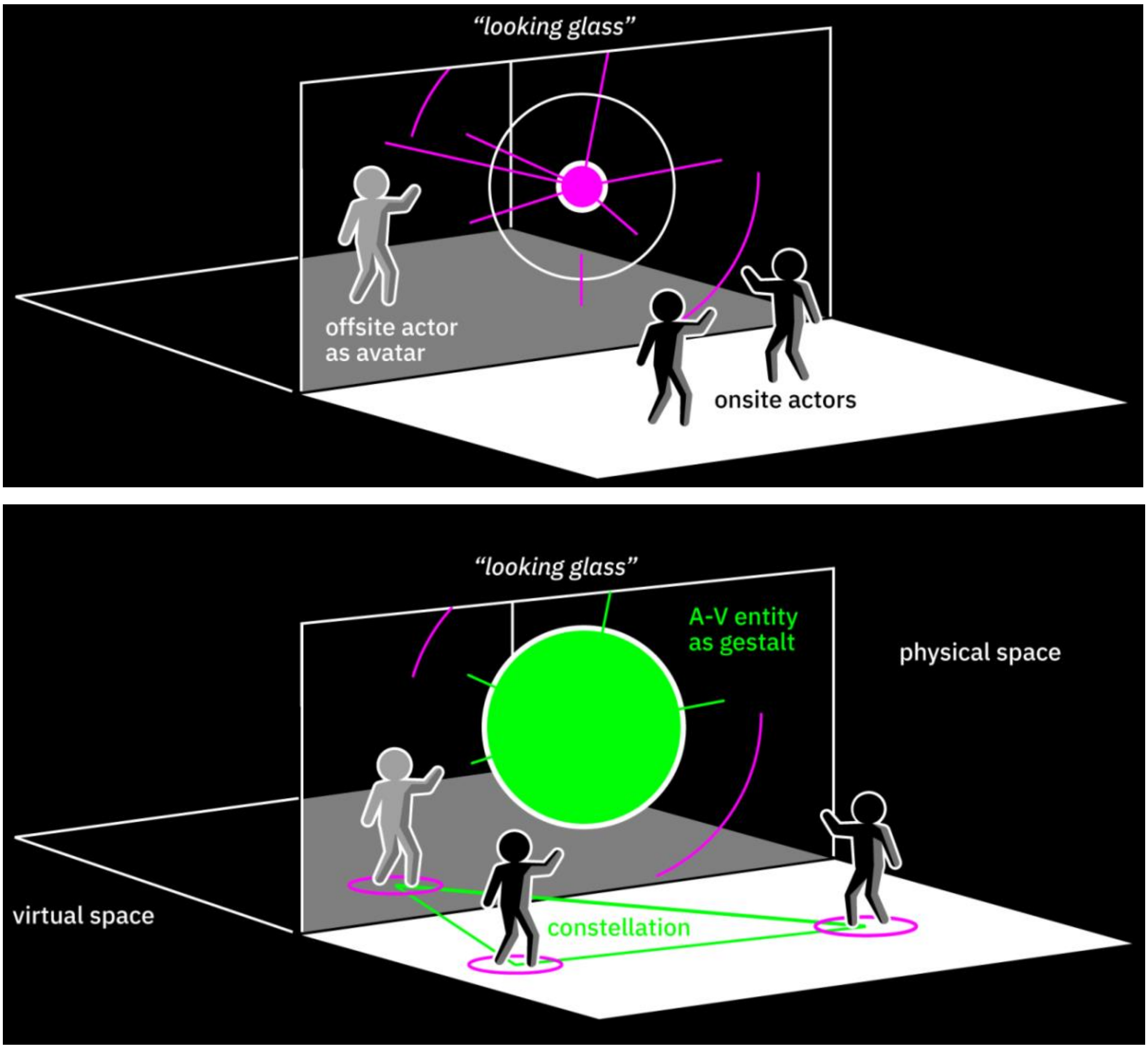

Figure 15 'Falcon Heavy' Concept work, Credit: Ars Electronica

Converge

Converge is a shared, social multiuser experience for deep space. Convergence follows a set of minimalistic, evolving scenes, each with crowd simulation at its core, each with its own spatial rules. Onsite and offsite users are represented by their respective avatars in these simulated crowd situations. Participants are in Deep Space or are joining remotely via HMD. In each shared scene the crowd simulation, the participants' avatars, and the space itself respond differently to the user interactions. Each scene can incorporate the concepts of amplification and synchronization in different ways depending on the collective goal. Key is to unravel a set of social puzzles and discover their intrinsic rules while exploring together as a group.

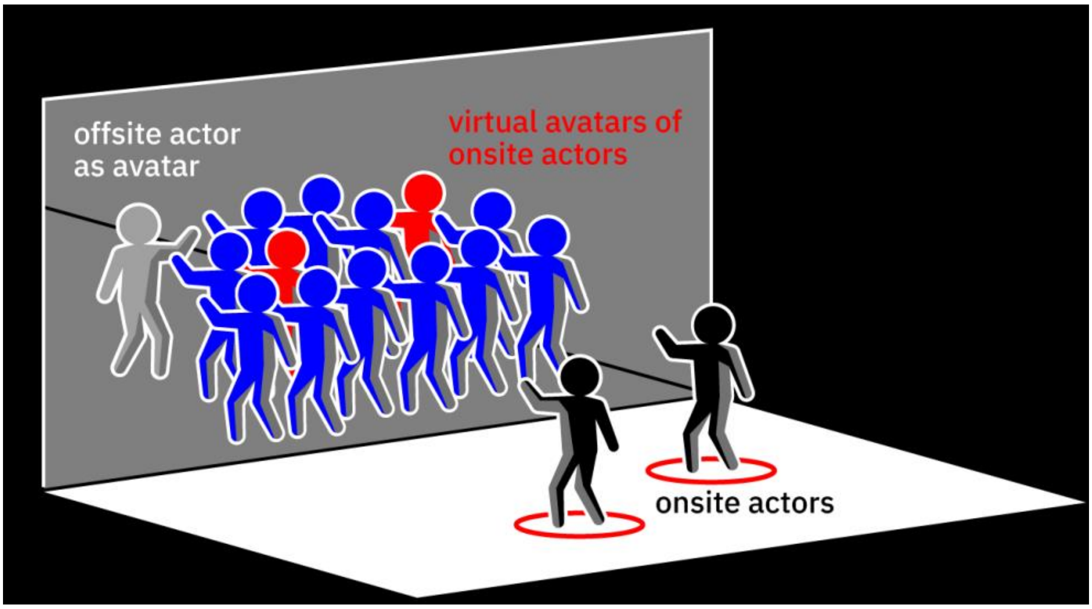

Figure 16. 'Convergence' concept work, Credit: Ars Electronica

Open Call Artist Recruitment

Additional to the Futurelab exploration, two artworks will be realized by external artists recruited through an Open Call. One artist will present their work during the Ars Electronica Festival 2024, and the other during the Ars Electronica Festival 2025. More information on the first completed round of Open Call can be found in the section below.

5.2 DELIVERY TIMELINE

The delivery timeline is depicted below in the Table 6.

Table 6 Timeline in an Art scenario deployment

ART	Task	STATUS
2023		
01-Jul	Setup and tests in Deep Space 8K with Golaem Avatars and a tracked person. License setup in Deep Space 8K.	achieved
02-Sep	Open call release	achieved
09-Sep	ARS ELECTRONICA FESTIVAL 2023	achieved
16-Sep	SHARESPACE v0.2	achieved
14-Oct	Potential information event about Open Call	achieved
21-Oct	Futurelab Art Scenario Concept Testing	
04-Nov	Presentation to consortium about concept futurelab art scenario	achieved
18-Nov	Open call #1 closed	achieved
16-Dec	SHARESPACE v0.3	achieved
23-Dec	Second UAB meeting, selection of Artist, discussion of futurelab art scenario	achieved
2024		
01-Jan	START TECHNICAL PRODUCTION OF FUTURELAB ART SCENARIO + UNREAL PLUGIN DEVELOPMENT	pending
Feb	ARTIST ONBOARDING: DEMO DEEP SPACE 8K + SHARESPACE PROJECT INTRO + COLLABORATION AGREEMENT (ONSITE IN LINZ)	pending
01-Mar	ARTIST DEVELOPMENT START	pending
26-Mar	SHARESPACE v1 - beta	pending
02-Apr	HANDOVER SHARESPACE v1-beta TO ARTIST	pending
04-Jun	AE PREMIERE FUTURELAB ART EXPLORATION (DATE NOT FIXED)	
11-Jun	SHARESPACE v1	
18-Jun	HANDOVER SHARESPACE v1 TO ARTIST	
16-Jul	THIRD UAB MEETING: EVALUATION FUTURELAB EXPLORATION + FEEDBACK ARTIST SCENARIO	
13-Aug	FINAL DATES FOR TESTS ARTIST	
03-Sep	ARS ELECTRONICA FESTIVAL 2024: PRESENTATION ART SCENARIO, SHARESPACE PANEL DISCUSSION, ANNOUNCEMENT OPEN CALL #2	
24-Sep	EVALUATION ART SCENARIO (D6.4)	

5.3 EVALUATION PROCEDURE OPEN CALL

The SHARESPACE Open Call 2023, the one recruiting artist(s) for the Ars Electronica Festival 2023, was announced during the Ars Electronica 2023, and was open for submissions between 10th of September 2023 and the 30th of November 2023. The overview of submissions can be found in the table below, and ultimately the evaluation went through three different phases. The content of the Open Call can be found here.

Open Call 2023

As mentioned above, the Open Call was first announced during the Ars Electronica Festival 2023 at the SHARESPACE booth placed in the Open Futurelab exhibition, and during the SHARESPACE Panel. Afterwards, the call was openly promoted on the SHARESPACE website and social media platforms and was circulated by the Ars Electronica network. Additionally, third party platforms for, for example, media arts and movement started picking up and promoting the Open Call without request from the consortium.

The initial deadline for the Open Call was on the 18th of November, but to increase the amount of completed submissions, the final deadline was pushed to the 30th of November. In the end, 152 applications were created in the application portal, and 61 of those were completed and could thus be considered.

First round of review

The goal of the first round of review was to curate a pre-selection of projects that all fit the SHARESPACE Open Call. The review was executed by members of the Futurelab and also included Futurelab members that were not actively working on the SHARESPACE projects in order to include outside perspectives. As mentioned above, 61 applications were completed and could be considered for review. Slightly over half of the applications were from female artists or included female artists in their group. Furthermore, the applications came from over 40 different countries, meaning that the dissemination strategies had a successful wide reach. Find in the figure below an overview of which countries participated in the Open Call.

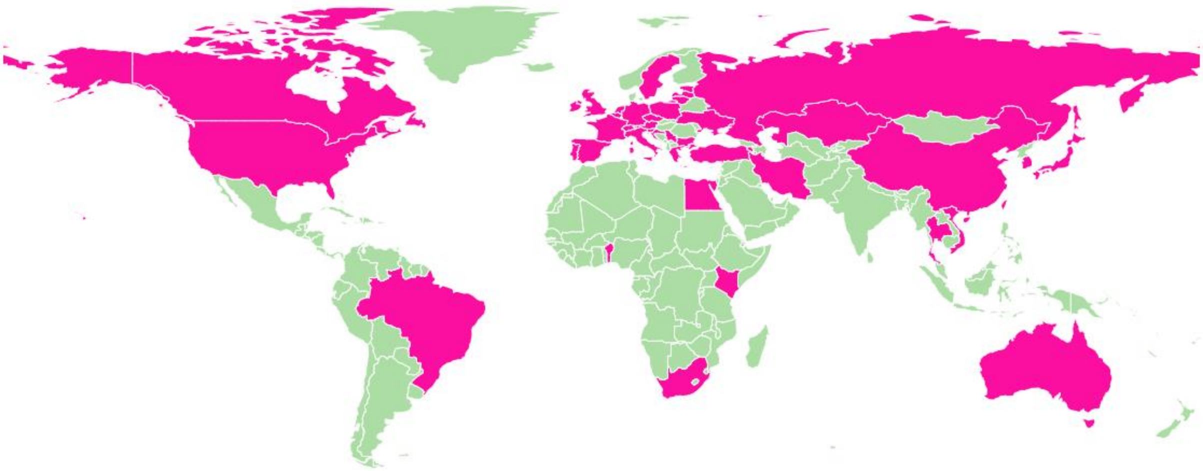

Figure 17. Overview of applying countries in the SHARESPACE Open Call 2023

The type of projects that were submitted for the Open Call include:

- Narrative-based theatre performances
- Dance performances
- Artists submitting previous work they want to show in the Deep Space setting
- Submission with high artistic value but not much connection to SHARESPACE
- Submitters with great Unreal Engine skills but low artistic values
- Researchers with good research skills that can have a good impact outside of the SHARESPACE project

During this initial review the reviewing body asked themselves the following set of questions:

- Does the artistic concept fit the call? Or can it be imagined to fit the call?
- Does the submission account for the required Unreal Engine skills?
- Do the artists have experience in performative settings?
- Is the artist suitable to work in a collaborative research project?

Taking the questions as the basis for the review and looking at the type of submission for the Open Call, some applications automatically fell away. For example, narrative-based theatre pieces would not fit the SHARESPACE project due to the focus on oral collaboration as opposed to embodied collaboration, and all the applications that presented finished work without considering the SHARESPACE project also fell away. In the end, 12 projects were deemed to fit the call and were taken to the next round of review.

Second round of review

The second round of review was hosted by the Ars Electronica Futurelab and included individuals from the SHARESPACE partners that were interested in reviewing the applications. During the meeting, nine partners participated. The goal of the meeting and the task of the SHARESPACE partners was not to share their opinions on 'favorite' projects, but to identify red flags in terms of their potential development. At the end of the meeting, six projects were chosen to be presented to the jury. After the meeting, all partners were given the chance to share comments on the six projects, and these comments were transparently shared with the jury members.

Jury Meeting

The jury consisted of the Artistic User Advisory Board that is put into place for the SHARESPACE art scenario. The meeting was held on the 15th of December 2023, lasted for 2,5 hours and was hosted by the Ars Electronica Futurelab. Its five members have extensive experience in the field of media arts, VR/XR, digital environments, art curation, and performance. On each of the final six preselected projects, the jury was presented with the following information:

1. Project concept
2. Artist(s) CV + portfolio
3. Motivation Letter
4. 4 Minutes video describing the artist(s)' motivation
5. Comments from the SHARESPACE consortium
6. Potential further visual material provided by the applicants

Each jury member reviewed the material provided before the meeting took place. In the end, one project was selected named 'State of Play' (working title).

Chosen project: State of Play

'State of Play' is a project suggested by a group of young artists from Berlin. The team includes 3D artists, art directors, digital artists, and game developers. The project's goal is to bring adults in touch with their inner child through the act of 'play'.

Highly influenced and inspired by videogame 'boss encounters', State of Play creates an expansive and interactive performance involving a central figure (offsite performer) and the onsite participants. In the immersive environment of Deep Space 8K, the floor projection functions as a game controller for the onsite participants, while the wall screen showcases gameplay. Both screens are utilized for cutscenes, enhancing the overall cinematic and immersive experience.

The onsite participants are actively involved in collaborative gameplay, reminiscent of guild-style raids, working together to confront a formidable avatar or 'boss,' portrayed by a motion-captured performer. The performance progresses through various phases, seamlessly transitioning between cutscenes and gameplay, building anticipation and concluding with an emotionally charged final cutscene. Drawing inspiration from traditional video game boss battles and Friedrich Nietzsche's philosophical exploration of the dialectics between the Greek gods Apollo and Dionysus in 'The Birth of Tragedy,' the piece undergoes constant transformation with changing arenas, checkpoints, and cutscenes.

The emphasis lies on collaborative teamwork and communication, fostering a shared approach rather than promoting violence for entertainment. The abstract nature of the boss ensures inclusivity among players from diverse backgrounds, as it prevents anyone from feeling offended or discriminated against. The success of the game lies in its ability to bring together players and social connection that extend into real-life interactions, as the audience collectively experiences care and emotions in real-time.

Jury Statement 'State of Play', dated 12.01.2024

The jury has thoroughly reviewed your submitted project and is happy to announce it is the selected project for the SHARESPACE Open Call 2023. The project demonstrates several positive aspects that contribute to its unique and innovative nature. However, certain reflection points need to be addressed to ensure the project aligns with the intended artistic impact and user experience.

<u>Positive Observations:</u>

Team Structure: We are convinced of the artistic and technological know-how of your team and are sure a piece can be realized that considers the many aspects necessary for this Open Call.

Innovative Structure: The project showcases an original approach by structuring itself as a computer game with interactive levels and non-interactive cutscenes. This design choice allows for the development of a compelling narrative arc and an increase in the complexity of group interaction from level to level. The concept of real individuals in Deep Space, represented by avatars, collaborating against a MoCap Suit-equipped "boss" introduces an intriguing dynamic. The incorporation of non-traditional group interactions adds depth and interest to the overall user experience.

Contemporary Aesthetics: The aesthetics of the project align with the current 'Zeitgeist', contributing to its visual appeal. However, it must be ensured they do not unintentionally mimic or closely resemble stylistic tendencies of specific games.

Reflecting upon this resemblance during the development process is crucial to maintain the project's originality.

Ethical Analysis and User Feedback: The commitment to performing an ethical analysis and collecting user feedback is commendable. It is encouraged to follow through on this commitment during the project's development to address any potential discomfort or controversy.

Reflection points:

Unconventional Shooter Elements: While the jury appreciates the intention to create an unconventional shooter, it is crucial that the project avoids traditional shooter elements. The development of alternative "weapons" and a reinterpretation of the "enemy" principle must be emphasized to fulfill this expectation.

Group Interaction Complexity: The interaction concepts for the group in Deep Space should strike a balance between depth and accessibility. It is essential that these concepts are not overly complex, allowing the group to grasp them quickly. Each level should present different interaction options to maintain variety and engagement.

Alignment on Research Concepts: The incorporation of the core SHARESPACE research concepts such as ‘amplification’ and ‘synchronization’ is somewhat lacking. However, we are convinced that through discussion and deliberation it is possible to align your vision with the project's goals in these areas.

In conclusion, the jury recognizes the potential of State of Play and encourages your Team to address the reflection points provided to enhance the project's overall impact and success. We look forward to witnessing the continued development of this artistic exploration.

Table 7 Overview of Open Call selection process

Overview table:

SHARESPACE Open Call 2023 overview		Reviewing body
Submissions in the portal	152	N/A
Projects selected for the first review	61	Futurelab members, including those not working on the SHARESPACE project
Projects selected for the second review	12	SHARESPACE Consortium
Projects presented to the jury	6	Artistic User Advisory Board

5.4 ON-SITE SETUP

The on-site setup is split up into two setups, one in the Deep Space 8K for on-site participants and the audience and one for remote participants. The Remote setup communicates to the Deep Space 8K setup, so the avatars of both sites are represented in the shared virtual environment.

5.4.1 Deep Space 8K setup

In the Deep Space 8K the active stereoscopic video is projected on the wall and the floor (see 4.5). The participants and the audience (spectators) are wearing active shutter 3D glasses. Audio is output via the built in 5.1/7.1 sound system. The primary input system for participants within the Deep Space 8K is PHARUS, a laser tracking system (consisting of 6 LiDAR units), which is capable of tracking 20 participants reliably. An OptiTrack system is also installed in the Deep Space 8K and can be utilized by the artists. One or more people within the Deep Space 8K may be equipped with a full or partial body tracking system and/or a VR or AR HMD. As an option, participants and spectators in the Deep Space 8K can be equipped with additional input and tracking devices. These can be wearables, for example, which enable the tracking of hand movements, button inputs or the measurement of vital data such as heart rate.

5.4.2 Remote setup

Remote participants are spatially separated from the Deep Space 8K. A remote participant wears an HMD, which is connected to a PC and is also equipped with a body tracking system.

In addition to the ALE Rainbow-based network, Unreal's Replication System will also be utilized. This allows us to respond more flexibly to the specific needs of the artworks and may help with the synchronization of arbitrary data.

5.5 RENDERING SPECIFICATION

Because multiple separate art pieces, which are designed by various artists, are distributed over two years, we face diverse requirements. The appearance of the avatars and the environment within the application can range from realistic to very abstract. As the pieces are in the conceptualization phase now, there is no detailed final information about the visualization. However, it is planned that single Golaem avatars are controlled by the participants. Furthermore, at least one artistic concept includes the rendering of a crowd of avatars.

Analog to on-site setup, the rendering (and processing in general) is separated into two parts. It is performed on two different systems. First the rendering in the Deep Space 8K, a large projection room, and second, for remote users, on HMDs. In Deep Space 8K the avatars of remote users are rendered. In addition, some but not all artworks might render the avatars of the on-site users as a kind of mirror image on the wall projection. As the remote users can see the whole scene, the avatars of all on-site users are rendered in the HMDs. In the Deep Space 8K, eight 4K projectors are driven by two PCs with two GPUs each. Even if those are powerful machines, the size of the rendered images (number of pixels) places considerable demands on hardware resources and imposes certain boundaries on the created content. The HMDs on the other hand, are mobile ones and therefore very limited in processing power. To bypass this limitation, they are connected to a PC.

Further functional and non-functional requirements can be found in the previous deliverable D1.2. Research Requirements for challenges and scenarios v1. Considerations for avatar design were previously addressed in D4.1: SHARESPACE avatar definition v1.

5.6 METRICS

- **The Spatial Presence Experience Scale** (SPES):
  https://dx.doi.org/10.1027/1864-1105/a000137
  self location, possible actions, SPES total
- **CSQ-VR** (Kourtesis et al., 2022):
  https://www.researchgate.net/publication/366400274_CyberSickness_in_Virtual_Reality_Questionnaire_CSQ-VR_A_brief_tool_for_evaluating_the_Virtual_Reality_Induced_Symptoms_and_Effects_VRISE?channel=doi&linkId=63a053fa024dc52c8a321083&showFulltext=true
  Cybersickness : 6 questions to assess three types of cybersickness symptoms (nausea, vestibular and oculomotor)
- **System Usability Scale** (Brooke, 1996): Brooke, J. (1996). SUS: a "quick and dirty‟ usability scale. In B. A. In P.W.Jordan, B. Thomas & and I. L. M. Weerdmeester (Eds.), Usability Evaluation in Industry (pp. 189–194). Taylor and Francis. Easy of use, intention of use
- **Virtual Embodiment Questionnaire** (Roth & Latoschik, 2020):
  https://doi.org/10.1109/TVCG.2020.3023603
  perceptual aspects of embodiment: ownership, agency, change.
- **Artistic experience and artistic value** (work in progress):
  Experiencing Flow While Viewing Art: Development of the Aesthetic Experience Questionnaire
  https://www.researchgate.net/publication/328176550_Experiencing_Flow_While_Viewing_Art_Development_of_the_Aesthetic_Experience_Questionnaire#:~:text=Aesthetic%20experiences%20are%20the%20attitudes,getting%20lost%E2%80%9D%20in%20the%20moment.
- **Flow state and social flow :**
  The Flow State Scale;
  https://journals.humankinetics.com/view/journals/jsep/18/1/article-p17.xml

Social Flow ;
https://www.researchgate.net/publication/348647626_Social_Flow

5.7 KPIs

In total, five different artworks will be shown. Two of them are conceptualized and developed, with support from Ars Electronica Futurelab, by artists or groups of artists who apply to an open call and are selected in jury process. One of these pieces will be shown during the Ars Electronica Festival 2024 and the other one 2025. The other three artworks are developed in the course of an artistic exploration phase by artists from the Ars Electronica Futurelab. These may be shown during the festivals, but also at other, earlier events. The following applies to all five artworks. There will be 2 – 10 people participating on-site in the performance in the Deep Space 8K. In addition, up to 60 spectators will be on-site in the Deep Space 8K, outside the tracked projection area. Each artwork will include at least one remote user, who wears full or partially body tracking and VR-HMD (see Table for overview of projected KPIs). The concepts of synchronization and amplification are incorporated in the different artworks to a different extent.

Table 8 Main projected KPIs for the Art scenario

		Working Title	Performances	On-site participants	Remote participants	Spectators
2024	1st Futurelab exploration	Convergence	2	2 - 10	1	30 - 60
	2nd Futurelab exploration	Falcon heavy	2	2 – 4	1 - 2	30 - 60
	1st External artwork	State of Play	1 – 2	2 - 10	1	30 - 60
2025	3rd Futurelab exploration	-	2	-	-	Up to 60
	2nd External artwork	-	1 – 2	-	-	Up to 60

5.8 OPEN EVENT DESCRIPTION 2024

The artistic exploration concepts that are developed by Futurelab are to be presented in the Deep Space 8K located at the Ars Electronica center prior to the Ars Electronica

Festival 2024. The showings and their corresponding participation are to be promoted in the context of SHARESPACE so participants are aware of the research goals of the project.

The artistic concept developed by the external media artist group will be shown at the Deep Space 8K during the Ars Electronica Festival 2024 taking place from 4-8 September in POSTCITY Linz. Ars Electronica is a festival for art, technology, and society, and pulls around 20.000 visitors to Linz every year. During the festival, artwork participation must be communicated properly as taking part in an active research project. This is necessary because participation requires the Ars Electronica team to collect data to engage in scenario evaluation.

5.9 RISK MITIGATION

Table 9 Breakdown of identified risks and mitigation strategies for Art scenario

Risk ID	Description of risk	Likelihood	Severity	Status	Responsible Partners	Proposed risk-mitigation measures
6.16	Deep Space: Visitors do not relate with their avatar.	Possible	High	Redressing	ARS	Early and continuous testing of the concept. Also with less or not involved people.
6.17	Deep Space: Artistic concept is misunderstood by the on-site participant, affecting the execution.	Possible	Medium	Redressing	ARS	Early and continuous evaluation of the concept.
6.18	Deep Space: The interaction concept is misunderstood or too complicated.	Not likely	High	Redressing	ARS	Early and continuous evaluation of the interaction design.

6.19	Deep Space: Cyber sickness due to moving virtual world/environment (e.g. could occur if the virtual camera performs movements).	Not likely	High	Prevention	ARS	Early and continuous evaluation of the concept.
6.20	Remote VR: A delay of tracking and/or avatar behavior causes a feeling of detachment or inhibits the interaction.	Not likely	High	Redressing	ARS	Early and continuous evaluation of the interaction design. If it cannot be solved or mitigated enough technically, the interaction design needs to be adapted.
6.21	Remote VR: The interaction feels cumbersome or too difficult.	Possible	Medium	Prevention	ARS	Early and continuous evaluation of the interaction design. Adaptation of the interaction design.
6.22	Remote VR: Low social presence	Possible	Medium	Redressing	ARS	Early and continuous evaluation of the interaction design. Evaluating different avatars and interaction/control strategies.

6.23	Remote VR: Cyber sickness.	Possible	Medium	Prevention	ARS	Early and continuous evaluation of the system. If it cannot be solved or mitigated enough technically, the interaction design needs to be adapted.
6.24	Remote VR: Delay of communication inhibits interaction	Possible	High	Prevention	ARS	Early and continuous evaluation of the interaction design. If it cannot be solved or mitigated enough technically, the interaction design needs to be adapted.
6.25	Technical difficulties integrating the technical components from the partners into the Deep Space 8K.	Possible	Medium	Redressing	ARS	Modification of the artistic concept. Potential reduction of the components from the partners. Or replacement of parts with those that have comparable functionality.

6.26	External artist recruited through the Open Call is unable to deliver the concept due to lack of technical expertise.	Not likely	High	Prevention	ARS	Modification of the artistic concept. Requesting the artist to use the budget to hire external contributors with technical expertise. Furthermore, provide sufficient guidance/support of the artist throughout the process.
6.27	External artist recruited through the Open Call is unable to deliver the concept on time.	Not likely	High	Prevention	ARS	Possibly employ the strategy that not the full 15.000 EUR will be paid up front, but part of it will be paid out after the delivery of the artwork (details not certain yet).
6.28	Latency from the SHARESPACE system architecture is hindering the realization of the art works in Deep Space 8K.	Possible	Medium	Redressing	ARS	Modification of the artistic concept. Or reduction of the components from the partners. Or replacement of parts with those that have a comparable functionality.

6.29	Not enough interest of participants to join the presentation and evaluation	Not likely	Medium	Prevention	ARS	Promotion before and during the Ars Electronica Festival by utilizing SHARESPACE communication channel and using the wider Ars Electronica Ecosystem.
6.30	Challenges with the remote collaboration with the external artist.	Not likely	High	Prevention	ARS	Establish clear communication protocols and tools to ensure seamless information exchange. Conduct regular virtual meetings to enhance collaboration and address any issues promptly.
6.31	Proper evaluation of the artistic scenario might prove challenging in the context of the wider Ars Electronica Festival.	Possible	Medium	Prevention	ARS	Proper communication about the participation in the artistic concepts, and proper management during the presentation at the Ars Electronica festivals.

6 APPROACH – QUESTIONNAIRES

We have created a repository of questionnaires across scenarios to provide a unified methodological framework across different deployment scenarios. These questionnaires are organized in Table 5 per scenario, with link to the questionnaire source and main output variables.

Table 10 Overview of questionnaires used to provide metrics for evaluation of scenarios

Scenario	Name of the questionnaire	DOI/link to information	Output variables
Art	The Spatial Presence Experience Scale (SPES)	https://dx.doi.org/10.1027/1864-1105/a000137	Self-location, possible actions, SPES total
Art	Artistic experience and artistic value	doi:10.1037/aca0000203	Openness to experience, inspiration, curiosity and exploration, flow
Art	The Flow State Scale	doi: https://doi.org/10.1123/jsep.18.1.17	Flow state.
Cycling	Slater-Usoh-Steed (SUS, Usoh 2000) -> to use during experiment (Schwind et al., 2019 : https://dl.acm.org/doi/10.1145/3290605.3300590)	doi :10.1162/105474600566989	Presence
Cycling	Technology Acceptance Model (TAM, Venkatesh & Bala 2008)	https://onlinelibrary.wiley.com/doi/10.1111/j.1540-5915.2008.00192.x	Perceived ease of use and perceived usefulness of the technology
Cycling/ Art/	CSQ-VR (Kourtesis et al., 2022)	https://doi.org/10.3390/virtualworlds2010002	Cybersickness : 6 questions to assess three types of cybersickness symptoms (nausea,

			vestibular and oculomotor)
Health	Brief pain Inventory Short Form (BPI, Cleeland & Ryan, 1994)	https://pubmed.ncbi.nlm.nih.gov/8080219/	severity of pain and its impact on functioning
Health	The Tampa Scale of Kinesiophobia (TSK, Miller, Kori & Todd, 1991).	https://journals.lww.com/clinicalpain/Citation/1991/03000/The_Tampa_Scale__a_Measure_of_Kinisophobia.53.aspx	pain-related fear of movement
Health	5-level EQ-5D version (EQ-5D-5L, Herdman et al., 2011)	https://doi.org/10.1007/s11136-011-9903-x	health-related quality of life
Health	Profile of Mood States (POMS-2A, Heuchert & McNair, 2012)	Heuchert, J. P. & McNair, D. M. (2012) Profile of Mood States 2. Multi-Health Systems (MHS), Toronto, ON	affect states. Six dimensions: anger-hostility; confusion-bewilderment; depression-dejection; fatigue-inertia; tension-anxiety; vigour-activity
Health	The Oswestry Disability Index (ODI, Fairbank & Pynsent, 2000)	https://doi.org/10.1097/00007632-200011150-00017	low back pain disability
Health/Art	System Usability Scale (Brooke, 1996).	Brooke, J. (1996). SUS: a "quick and dirty" usability scale. In B. A. In P.W.Jordan, B. Thomas & and I. L. M. Weerdmeester (Eds.), Usability Evaluation in Industry (pp. 189–194). Taylor and Francis.	easy of use, intention of use
Health/Art	Virtual Embodiment Questionnaire (Roth & Latoschik, 2020).	https://doi.org/10.1109/TVCG.2020.3023603	perceptual aspects of embodiment: ownership, agency, change.

Health	Virtual Human Interaction Lab Presence Scale (Han, Miller, Ram, Novak & Bailenson, 2022)	https://vhil.stanford.edu/	social presence, self-presence, and spatial presence.
Health	Technostress Creator Stress (TCS, Ragu-Nathan et al., 2008)	doi:10.1287/isre.1070.0165	techno-overload (increased workload); techno invasion (work-home conflict); techno-complexity (feeling of inadequacy due the complexity of the ICT and spending time and effort to learn and understand them); techno-insecurity (feeling threatened by the ICT); techno-uncertainty (constant changes associated to technologies
Health	Simulator Sickness Questionnaire (SSQ, Kennedy et al., 1996).	doi: 10.1207/s15327108ijap0303_3	occurrence of 16 symptoms classified in three categories: oculomotor, disorientation, and nausea due to the VR experience
Health	Elliot and Harackiewicz's (1996) intrinsic motivation scale	https://doi.org/10.1037/0022-3514.70.3.461	intrinsic motivation
Health	Ng et al.'s (2011) relatedness scale of the Basic Needs Satisfaction in Sport Scale	https://doi.org/10.1016/j.psychsport.2010.10.006	relatedness
Health	Teboul et al.'s (2019) Approach-Avoidance System Questionnaire	doi:10.3389/fpsyg.2019.02531	competence expectancies (e.g., For the next session, I feel up to the task), benefit for the self (e.g., If I succeeded in the task of the coming session, I would be proud of myself), and threat for the self

7 CONCLUSIONS AND FUTURE WORKS

In conclusion, the Real-World Scenarios Evaluation within the SHARESPACE project, coordinated by UM, is a crucial aspect aimed at assessing the effectiveness of our technology across three high-impact areas: Health (Social Low Back Pain Exergame), Sport (Peloton Cycling), and Art (Shared Creativity). The timeline and planning is summarized in Figure 15.

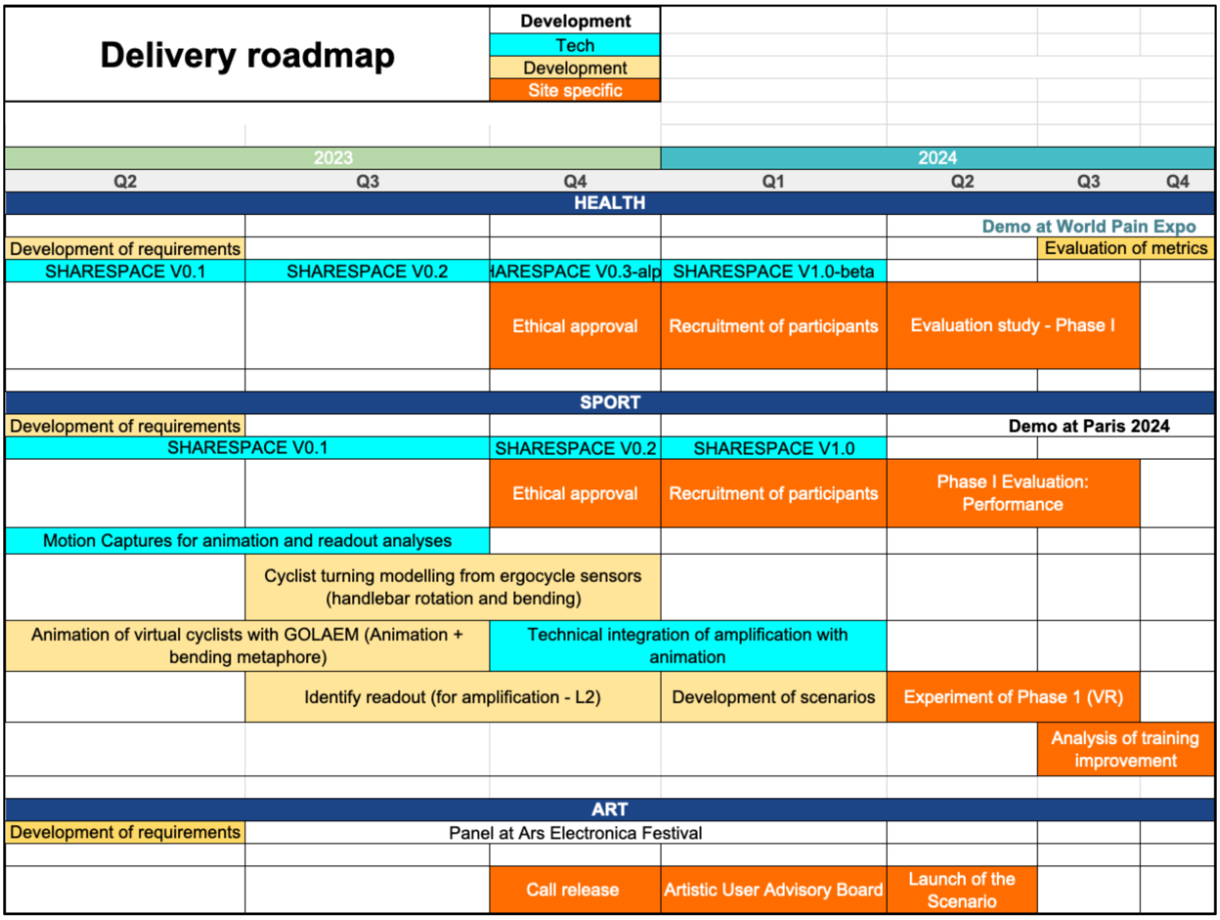

Figure 18. Delivery roadmap for the Scenario Planning and Evaluation

These scenarios, carefully selected based on the expertise of our consortium partners and upcoming international events, encompass various levels of autonomy, ranging from human representation at the avatar level to virtual autonomous characters. The demonstration of SHARESPACE technology feasibility with specific Key Performance Indicators (KPIs) is the interim goal of the evaluation.

The selected events for showcasing our scenarios, including The World Congress on Pain, the Olympic Games in Paris, the Tour de France, and the Ars Electronica

Festival, provide an excellent platform to highlight the capabilities of SHARESPACE technology. The research delivery roadmap, consistently updated for all scenarios, ensures diligent monitoring of progress.

Recognizing the inherent risks associated with the implementation of new systems and technologies, we have systematically identified, analyzed, and prioritized potential challenges through a comprehensive risk assessment process (documented in deliverables D1.2 and D8.1). This proactive approach allows us to develop effective risk management strategies, seamlessly integrating them into user requirements and technical safety rules.

In essence, SHARESPACE is not just a technological endeavour but a meticulously planned and executed initiative to push the boundaries of innovation but also addresses challenges head-on society. The collaboration between diverse expertise from VHIR, INRIA, and AE, combined with strategic event partnerships, positions SHARESPACE at the forefront of cutting-edge technology implementation. As we continue to move forward, the insights gained from this comprehensive evaluation process will undoubtedly contribute to the success and sustainability of SHARESPACE across diverse real-world scenarios.

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Measures: Self-location, possible actions.