D8.13

Final Demonstration Tool

Version
V1.0

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Project	**Deliverable**
MED1stMR	D8.13
Project number	**Deliverable Lead**
101021775	RFNS
Type of Action	**Related work package**
RIA	WP8
Start date of project	**Dissemination level**
01.06.2021	Public
Duration	**Due submission date**
36 months	31.01.2024
	Actual submission
	31.01.2024

Versions

Version	Date	Author(s)	Description
V0.1	01/12/2023	Helmut Schrom-Feiertag (AIT) Vendula Rajdlova (AIT)	First Draft with document structure
V0.2	20/12/2023	Matthias Dieterle (RFNS)	Including content with the respective descriptions
V0.3	26/01/2024	Matthias Dieterle (RFNS)	Updating document with latest images from the last field trial and some additional information
V1.0	30/01/2024	Helmut Schrom-Feiertag (AIT) Vendula Rajdlova (AIT)	Final formatting and uploading

Report Review

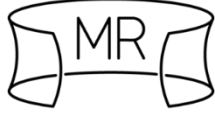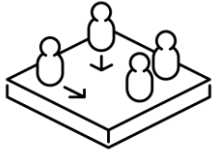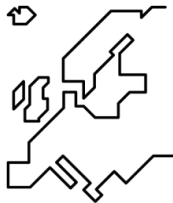| Version	Date	Reviewer(s)	Statement
V0.2	22/12/2023	Helmut Schrom-Feiertag (AIT)	Include description of changes during field trials and provide actual images from the system
V1.0	31/01/2024	Helmut Schrom-Feiertag (AIT) Vendula Rajdlova (AIT)	Final review

HSchrom
31.01.2024

RajdlovaV
31.01.2024

List of Acronyms and Abbreviations

Acronym/ Abbreviation	
EDA	Electrodermal Activity
EPME	Effective Performance in Medical Emergencies
GUI	Graphical User Interface
HMD	Head-Mounted-Display
HR	Heart Rate
HRV	Heart Rate Variability
MAS	MED1stMR Analysis and Statistic
MCI	Mass Casualty Incident
MR	Mixed Reality
NPC	Non-player character
PC	Personal Computer
UI	User Interface
VR	Virtual Reality

Relation to Objectives

Objective	Description
	Obj. 1: Pioneering MR training approach for enhanced realism The MR Trainings Environment is the main objective by building the basis for the execution of MR trainings. It was tested in six field trials and further developed to the final system and its components which is documented in this deliverable. It consists of the MR scenario editor, exercise control, the integrated smart wearables, and the high-fidelity manikin to create the new extended MR training system to train emergencies with high-risk and demanding situations with high realism.
	Obj. 2: Effective training scenarios and a training curriculum With the developed scenario editor and the provided 3D assets for the virtual environment, the virtual patients with its wounds it is easy to create and adapt scenarios. Two scenarios were defined and evaluated about their effectiveness during the six field trials.
	Obj. 3: Physiological signal and trainee behaviour feedback loop and smart scenario control The integrated wearable devices for physiological data collection will be visualized in real-life for stress assessment during training and recorded and visualised for the debriefing and contributes to a comprehensive assessment of trainees' performance during training and for smart scenario control as well as deepening learning after training in the debriefing.
	Obj. 4: Position the pioneering MR training approach across Europe The MR training system was tested in six field trials across Europe and tested with over 200 trainees. The innovative system demonstrated an enhanced training approach and generated interest among medical first responder organizations throughout Europe, promoting the exchange of knowledge between countries and end user organisations.

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Executive Summary

The MED1stMR project has developed a novel mixed reality training solution for medical first responders, which integrates real-world medical simulators and virtual environments to simulate various mass casualty disaster scenarios. The final demonstrator has the following features:

- A **large training environment** with optical tracking for precise and simultaneous motion tracking of up to 4 trainees.
- An **operator station** for training execution that enables trainers to manage and control immersive MR training scenarios.
- A **spectator station** where visitors can observe trainees' activities through large screen showcasing the dynamic training content and the participants' interactions within the MR environment.
- **Realistic 3D environment** objects that correspond to the mass casualty incident scenarios.
- A library comprising **25 diverse patient avatars**, each representing typical injuries resulting from a bus accident.
- A **scenario editor** that easily allows instructors to create and customize virtual environments and training scenarios using the created 3D objects and patient avatars.
- **Two mass casualty incident scenarios** with a bus crash in different environments: one in a country road and the other within a tunnel.
- A **high-end medical simulation manikin** that provides haptic and realistic feedback in the virtual environment.
- A **wearable biosignals measurement device** that monitors stress levels of trainees and their changes during training in real-time.
- A **real-time visualisation** tool that shows the **stress levels** of individual trainees and enables trainers to make data-driven decisions.
- The **debriefing solution** that allows instructors and trainees to review and analyse their performance and feedback after the mixed reality training session in the 3D scenario environment.
- An **analysis and statistic tool**, a web-based dashboard that displays various metrics and indicators of the trainees' performance.

The final demonstration tool of the training solution is the result of six field trials that were conducted by the partner´s end user in six different European countries with around 200 medical first responders. The field trials provided valuable feedback and data that helped to improve the usability, functionality, and effectiveness of the training solution. The main technology components of the MED1stMR training solution will be presented and explained in detail in the following sections, with a focus on highlighting their functionality and application. The final demonstration tool will be showcased at the MED1stMR final conference on April 17th & 18th 2024 at Campus Vesta in Ranst, Belgium.

The current iteration of the MED1stMR Final Demonstration Tool shows an advanced stage of development, featuring two thoroughly designed base scenarios. This sophisticated tool is characterised by its adaptability and extensibility of scenarios, which is easily enabled by the intuitive scenario editor. This capability needs to be further enhanced to allow users to customise and extend scenarios to meet evolving training requirements.

Centrally focused on first triage training, the MED1stMR Final Demonstration Tool composes immersive simulations for teams up to four medical first responders. Through the deliberate recreation of authentic triage scenarios, the tool serves as a catalyst for refining responders' critical decision-making and operational capabilities.

The tool's paramount significance lies in its strategic optimization of training resources. In contrast to infrequently executed traditional real-life exercises constrained by resources and logistical challenges, this tool fosters regular and accessible training sessions. This approach not only cultivates a heightened proficiency among medical responders but also ensures a consistently elevated state of preparedness throughout medical teams.

In summary, the MED1stMR Final Demonstration Tool heralds a transformative epoch in medical response training, providing an efficient training solution that maximizes training efficacy while judiciously managing resources. Looking ahead future iterations will integrate improved tracking technologies and machine learning algorithms, to enhance realism and adaptability. These advancements will continue to redefine the landscape of medical response training, ensuring that responders remain at the forefront of preparedness and efficiency in addressing emergent situations.

Relation to other deliverables and tasks in MED1stMR

Table 1: The work and the document build on results from the following deliverables.

No.	Title	Information on which to build
D2.2	End Users Perspective: Requirements Report, Stakeholder Map and Expectation Summary for Smart Wearables, MR Training Framework and Curriculum	The end user requirements are the foundation for all developments of the MR training environment including the manikin features and the wearables for biosignals measurements.
D2.3	Guidelines and Inputs for the future Training Scenarios	The developed guidelines were used for the collaborative creation of the two training scenarios.
D2.4	High-Level System Architecture	The high-level system architecture serves as the fundamental blueprint for the technical structure of both hardware and software components. It lays the foundation for a well-integrated and robust system that facilitates seamless interactions and optimal performance.

D4.1	MR Technology Framework for Responsive Human-Manikin	By establishing a clear and well-defined technology framework, the document outlines the essential components, functionalities, and requirements for the responsive manikin's design and implementation. It serves as a reference point for developers, engineers, and designers, ensuring a unified understanding of the desired outcomes and capabilities of the manikin.
D4.3	Activity Recording for the Exercise Debriefing	The document guides our MR system debriefing development. Real-time tracking captures trainees' interactions with virtual scenarios and manikins, enhancing personalized debriefing and skill improvement in medical training.
D4.4	Physiological signals Acquisition Hardware and Software Framework	D4.4 describes wearables hardware, data acquisition software, and proper usage. It outlines wearable selection, data processing, and analysis for accurate physiological data during training. Guidelines ensure effective usage, enhancing training outcomes.
D5.1	VR System Design Document and Evaluation Plan for MED1stVR MR Trainings Environment	D5.1 outlines the MR system design and evaluation plan for the mixed reality training environment. It provides details on the architecture and components of the MR system, ensuring seamless integration.
D5.2	MR Trainings Environment, Trainings-Scenarios and MR Live Editor infrastructure for conducting the Evaluations	This report describes the technological basis at the beginning of the field trials and forms the starting point and main content of this deliverable, expanded and supplemented with the developments and improvements made during the field trials.

Table 2: The results of this work will be incorporated into following work and developments

No.	Title	Basis for
D6.3	Report on the MED1stMR Demonstration at the Final Conference	The final demonstration tool will be demonstrated at the final conference and can be tested by conference participants. The report will also include feedback from these test persons on the system.
D6.5	MED1stMR Final Evaluated VR Training Scenarios	This report provides the basic description of the training system including the two scenarios which were evaluated in the field trials.
D6.6	MED1stMR Final Guidelines for VR Training	This report provides information about the use and operation of the system and forms a basis for the final guidelines.

D6.7	MED1stMR Final Training Curriculum for EPME	Describes the implementation of MR training in the curriculum for medical first responders and builds on this document describing the usage.
D7.1	Concluding reflection and knowledge of the technologies in relation to the different emergency scenarios	The reflections and knowledge of the technologies will refer to the single component descriptions in this deliverable.
D7.2	Implementation concept of MR training by end users	Describes the implementation in MR training based on this description and extended with results from further deliverables.
D8.12	Exploitation Plan and Business Outlook - final	This description of the system with all its components forms the basis for the exploitation plan and business outlook

1   Introduction

The starting point of the final demonstration tool was the technical basis at the beginning of the field trials as described in deliverable D5.2, which was iteratively refined and systematically improved. The aim of this development was to create a sophisticated virtual training simulation environment that fulfils the requirements of end users. The overarching goal in the progress was to provide medical first responders (MFRs) with a training platform that reflects the complexity of real-life emergency scenarios and facilitates training goals to be addressed.

A decisive improvement of the mixed reality trainings was the integration of the two manikins. This integration broadens the spectrum of medical emergencies that can be authentically simulated, fostering a more comprehensive mixed reality hands-on training experience.

In addition, non-player characters (NPCs) triaged green now move along paths to a gathering area and exhibit realistic behaviours as they navigate through other standing and sitting virtual patients, increasing the overall authenticity of the simulation. Furthermore, the introduction of diverse NPCs showcasing various injuries amplifies the complexity of diagnostic and treatment scenarios, enriching the training environment with nuanced challenges.

A key criterion for measuring stress is recording the trainees' individual baseline. This baseline is now recorded once after the improved integration in the initial scenario, stored and used as a reference for the other scenarios in order to determine changes in the stress level.

A critical focus has been placed on heightening realism. NPCs exhibit more lifelike movements, and patient sounds have been intricately incorporated into the simulation to amplify immersion. Adjustments in the virtual avatar size and shape, representing the physical manikins, contribute to an even more authentic training environment.

Facilitating seamless interaction, a user-friendly graphical user interface (GUI) now streamlines the biosignals sensor connectivity. This GUI not only simplifies the connection process but also incorporates a feedback mechanism and allows the utilization of pre-established baselines, optimizing user engagement and efficiency.

The system's sophistication extends to dynamic features such as automated bleeding cessation upon tourniquet application. Simultaneously, the respiratory rates of NPCs have been rendered more visible, affording medical practitioners enhanced diagnostic insights during training scenarios.

This continuous refinement process emphasises the commitment to providing an innovative training platform that embodies professionalism and attention to detail for the benefit of the medical community. In the following chapters, detailed descriptions of the components and features will be provided, offering a comprehensive understanding of the system's functionality and capabilities.

2 System Setup

2.1 Overview

The MR training environment is a cutting-edge platform designed to provide an immersive and interactive learning experience. This innovative system seamlessly integrates virtual elements with real-world elements, utilizing simulation manikins to simulate authentic patient scenarios and thereby creating a lifelike training environment. The following Figure 1 shows an overview of the essential components and setup of a mixed reality training system.
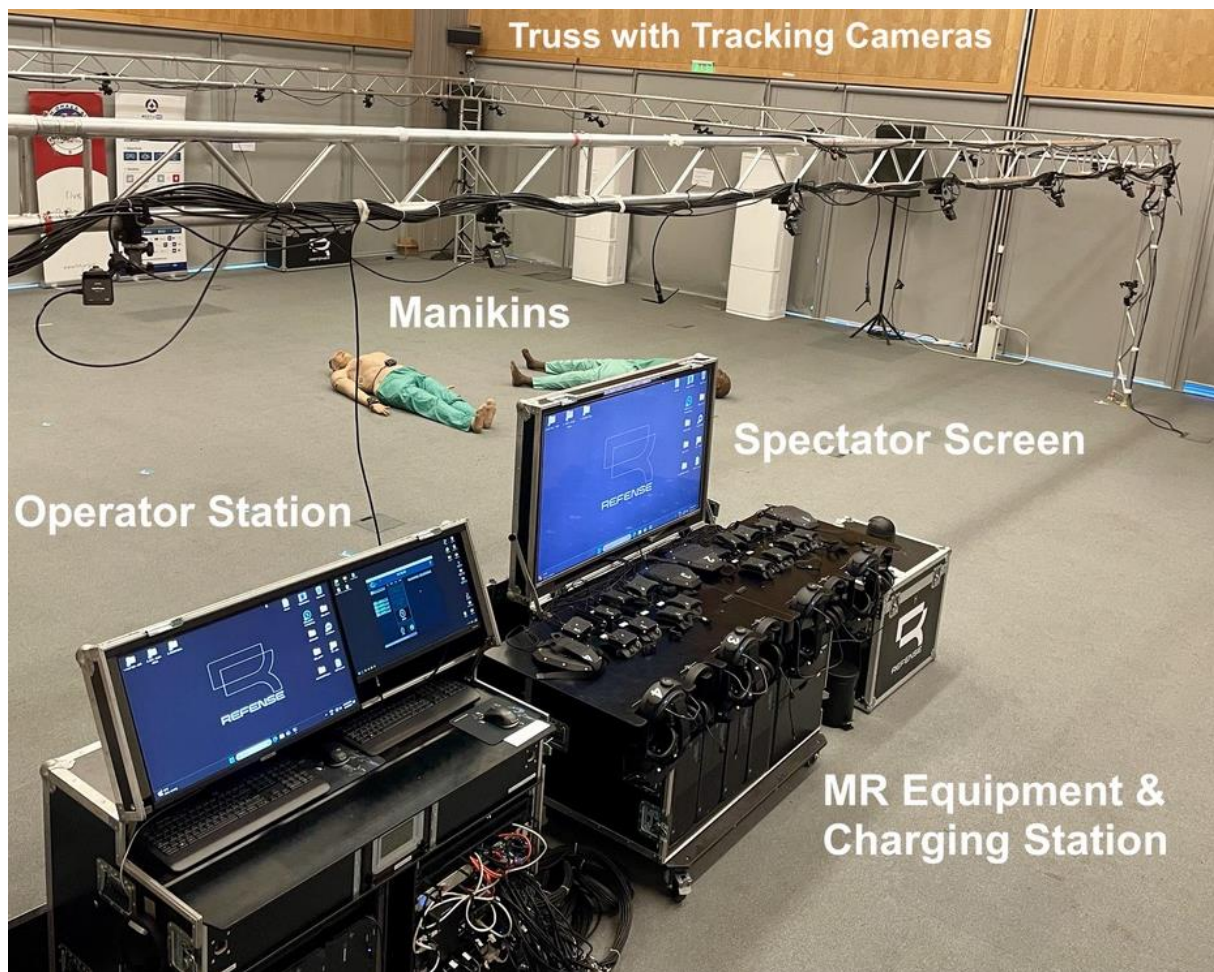
Figure 1: MR training environment showing operator station, spectator station, stage truss setup and manikins.

Tracking cameras are securely mounted on the truss surrounding the training field and connected to the main computer for stable and optimal coverage. The setup's efficiency and ease of use make the field trial experience seamless and immersive. The thoughtful organization and accessible design facilitate smooth operation for both operators and the audience, contributing to a successful and engaging field trial.

The field trial setup was designed to be user-friendly, featuring two flight cases equipped with high-performance computers. Assembly is straightforward, requiring only a minimal number of cables for connections. The virtual scenario can be observed effortlessly by both the operator and spectators through designated links: The operator's station on the left and the spectator's screen on the right (Figure 2).

Figure 2: Operator station and spectator station of the MR setup.

The single components with operator station, spectator screen, and MR equipment are described in the following sections.

2.2 Operator Station

The MR operator station for training execution is a powerful control centre that enables trainers to manage and control immersive MR training scenarios. It features a high-performance computer system, a specialized MR headset, and intuitive controls. Trainers can manipulate virtual environments, provide real-time guidance to trainees, and monitor their progress from different views (top view, perspective from a trainee, or free camera position). With hands-on interactions and seamless collaboration, the MR operator station empowers trainers to create dynamic and effective training experiences, enhancing skill development in a safe and engaging mixed reality setting.

Figure 3: Operator Station

The MR system operator seamlessly communicates with trainees via a headset, facilitating real-time guidance in the introduction phase and instruction during training sessions and can also act as a simulated situation centre.

2.3 Spectator Station

The MR spectator station offers an engaging view of immersive training scenarios. Visitors can observe trainees' activities through large displays and witness the seamless integration of virtual elements with the real-world environment. The station provides an informative and captivating experience for spectators, showcasing the dynamic training content and the participants' interactions within the MR environment. It allows visitors to gain insights into the training process, perceive trainees' decisions and skill development, and appreciate the benefits of MR training in a concise and visually compelling manner.

Figure 4: Spectator Screen with (left) the top view and (right) the view from the perspective of a trainee.

2.4 MR Equipment

The MR equipment combines a cutting-edge full body tracking system and a state-of-the-art wireless headset to create an unparalleled training experience. With our full body tracking system, every move a trainee makes is accurately reflected in the virtual environment, allowing for natural and realistic interactions with the training scenarios. Whether practicing complex manoeuvres or refining essential skills, the full body tracking ensures that your actions seamlessly translate into the virtual world.

The wireless HMD (Head-Mounted-Display) adds another dimension of freedom to the training without limitations of cords and cables or wearing a PC on the back, allowing to move effortlessly and explore the virtual space without any hindrance. The wireless design provides a truly immersive experience, untethered from the physical world, and fully engaged in the training environment. The MR equipment opens up a realm of possibilities, where trainees can practice, learn, and grow in a safe and dynamic setting. For added convenience, the MR equipment can be easily attached to marked stations for charging purposes (Figure 5).

Figure 5: Charging station for the MR-equipment.

2.4.1 VR– Equipment overview

This section provides step-by-step instructions for turning on the VR equipment, cleaning it after each training session, and equipping participants with the VR equipment. Each participant has the same equipment, which includes: Two hand sensors, two foot sensors, one back sensor, a VR headset and headphones. The individual components are depicted below in Figure 6.

Hand & Foot Sensor   Back Sensor   VR Headset & Headphones

Figure 6: MR equipment for a trainee.

The following Figure 7 depicts a trainee fully equipped with MR gear, illustrating the complete setup utilized for immersive training experiences.

Figure 7: Fully equipped trainee in action.

2.4.2 Instructions MR equipment

In the following instructions for the MR equipment, detailed guidance is provided on powering on the system, ensuring proper cleaning protocols to maintain hygiene standards, equipping the trainee with the necessary gear for immersive training experiences, and the correct procedure for disassembling the equipment after use. Each step is outlined accurately to ensure smooth operation and optimal performance of the MR setup.

2.4.2.1 Step 1: Power on the MR equipment

The steps for power on the MR equipment are shown in the following Figure 8. To start the MR headset model HTC Vive Focus 3, press and hold the power button on the battery for approximately 5 seconds until the LEDs begin to illuminate.

Power on: Press down on the button for ~1 second to turn on the puck. It will illuminate the top LED in orange for a few seconds until it initializes.

Power button

Powered on and connected to base station, puck is ready to use

Powered on and connected to a Base Station

Figure 8: Powering on the VR equipment.

2.4.2.2 Step 2: Clean VR equipment

The VR headset and headphones need to be cleaned after each training session. In particular, the lenses of the VR headset must always be kept clean to ensure a clear view into the virtual world. When

cleaning, it is important to use only the microfiber cloth specifically designed for cleaning the VR lens, without any liquid, as using liquid can permanently damage the lens. Disinfection wipes are used for cleaning the VR headset faceplate and the headphones. The illustrations below indicate in green what can be cleaned with each respective cleaning cloth.
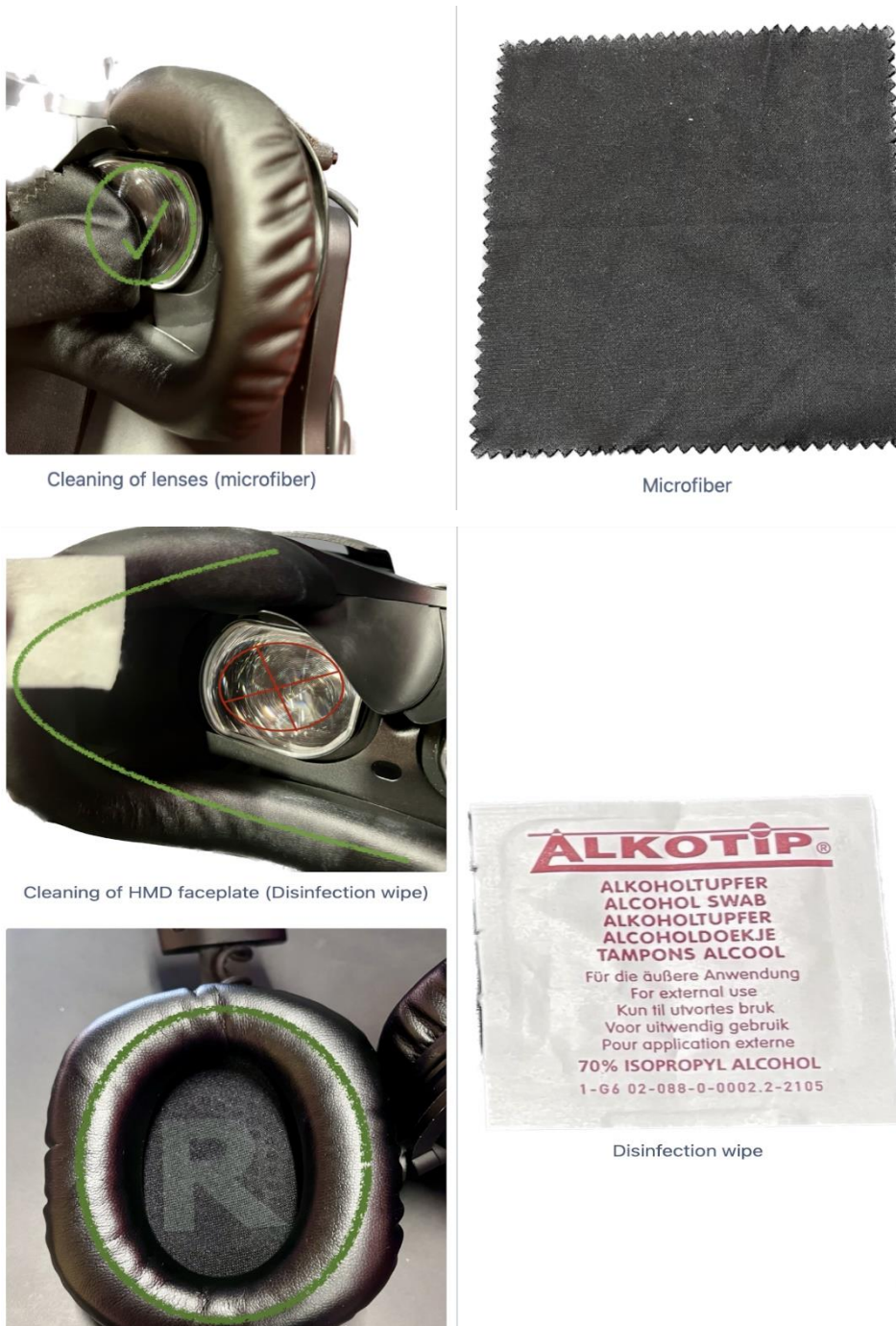
Figure 9: Cleaning the VR equipment.

2.4.2.3   Step 3: Equip with VR equipment

Before wearing the VR equipment, ensure that the sensors and VR headsets are powered on and clean.

Each participant has their own VR set, which can be identified by the number displayed on the VR equipment (e.g., VR Set 1: the foot, hand, and back sensors, as well as the VR goggles, will have the number 1 on them). Additionally, the hand and foot sensors will have the letters "R" for right and "L" for left. When equipping, it is important to note that the numbers on the sets should match, and the right sensors should be placed on the right side.

- Start by putting on the foot sensors, ensuring that they are oriented correctly (the numbers and letters are readable for the participant) and placed on the appropriate side. The foot sensor has two rubber bands, with the rear one being placed over the heel and the front one secured below the foot.
- Next, put on the hand sensors in the correct orientation and on the correct side. The hand sensors rest on the back of the hand, with the participant first sliding their hand through the wrist strap and then fastening the elastic band in the center of the hand near the little finger. Finally, the little finger, ring finger, and middle finger go into the designated openings on the hand sensor.
- Place the back sensor on the back and fasten the attached elastic band with the corresponding click closure around the abdomen.
- Finally, put on the VR goggles with the headphones. The size of the VR goggles can be adjusted using a wheel at the back of the head for a tighter or looser fit. The participant should tilt the goggles slightly up and down until the image seen through the VR goggles becomes clear.

The illustrations below provide a visual representation of the equipment setup for better understanding.

Tightened foot sensors with visible positioning of the rubber bands

Hand sensor with wrist strap and designated finger openings

Hand sensor with wrist strap and designated finger openings

Tightened back sensor

Tightened headset and headphones

Figure 10: Visual illustrations of the equipment setup for better understanding.

2.4.2.4   Step 4: Disassembling and charging the VR equipment

After the training session, the VR equipment is set aside, cleaned (Step 2), and placed on charge. It is important to note that the VR headset should be laid down on the table with a slight tilt to ensure the cable attached at the bottom remains undamaged. The hand, foot, and back sensors are charged in the same manner by connecting them to their respective magnetic charging cables. As depicted below, the VR headset is charged using the charging port located at the back of the headpiece. Regular charging of the VR headset is recommended, as it has a maximum battery life of 2 hours per charge.

- Only charge the trueVR Active Puck Tracker with a micro USB cable from a USB power source (5V DC).
- Approximately 2 hours for a full charge

Figure 11: Charging of the equipment.

2.5 Scenario Execution

To initiate a scenario, the VR equipment is first explained to the trainees and set up. The next steps are starting the MR system and connect the smart wearables including the biosignal sensors to the system.

2.5.1 The operator GUI

The Operator- GUI (Graphical User Interface) is then launched with the selected players, and the training session begins (Figure 12).
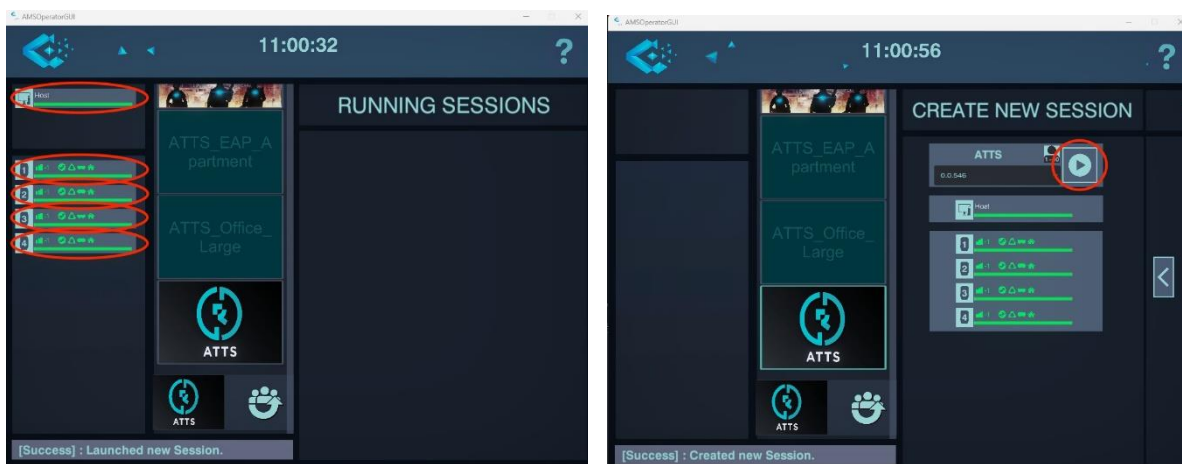
Figure 12: Operator GUI indicating that all VR headsets are selected and ready.

The GUI is designed to be intuitive, allowing the operator to quickly identify and address any issues that may arise. During the training session, participants are granted the freedom to explore the virtual environment, choose their preferred characters, and perform quick calibrations to adjust the body dimensions. The session involves interacting with two mannequins, providing valuable opportunities to practice triage card assignments. While one of the mannequins can be moved around, the other remains fixed at a specific location marked by a ground marker. Before proceeding, participants should wait for the PLUX wearable connection to be established. The operator can easily accomplish this by selecting the PLUX device group designated for the session. Subsequently, they can rely on the intuitive GUI to determine when the PLUX devices are connected — denoted by colour feedback of red (disconnected) or green (connected), see next chapter 2.5.2. Once the PLUX wearables are successfully linked, the session kicks off with a baseline heart rate test initiated through a GUI button. Participants are instructed to maintain focus on the plus sign for two minutes without any movements. Further details about the PLUX wearables can be found in D5.4.

In the virtual lobby (Figure 13), all necessary preparations are completed, and stress visualizations will no longer appear grey, signalling that the scenario is ready to begin. Participants then gather at the designated start area to commence the scenario. The stress visualizations are continually updated with PLUX data and will appear in different colour code once the data is received. During the scenario, participants can carry out triage tasks using the triage cards and tourniquets located on their left and right arms. Additionally, the operator can relocate all green NPCs (mannequins) to the safety zone using a designated button. Upon completion of the scenario, it is crucial to click the "stop data gathering" button, as this is vital for the purpose of replay and data collection. Following a brief waiting period to ensure that all files are transferred, the training can be concluded.
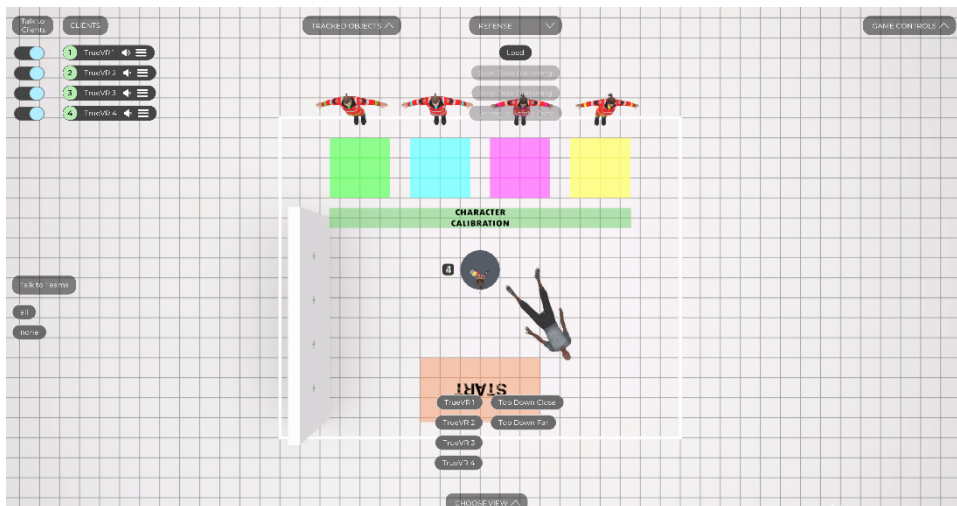
Figure 13: Virtual lobby for introduction, calibration and baseline measurement.

2.5.2 Connecting the biosignals sensors

In MED1stMR the integration of PLUX biosignals sensors within mixed reality environments are a pioneering approach to enhance learning outcomes. This innovative fusion combines immersive technologies with physiological monitoring to provide invaluable insights into trainee performance, particularly in assessing stress levels during training scenarios. Stress, often regarded as a significant impediment to effective learning and performance, can manifest in various forms and intensities, impacting cognitive functions, decision-making abilities, and overall well-being. Recognizing the pivotal role of stress management in optimizing training efficacy, the integration of biosignals sensors offers a multifaceted solution to monitor and mitigate stress responses in real-time. By leveraging advanced algorithms these sensors translate raw physiological signals into actionable insights, facilitating a comprehensive understanding of the trainee's stress dynamics throughout the training session.

Two Wearables are used to access the user stress score, the cardioBAN for heartrate and heart rate variability and the edaBAN for the galvanic skin response data (see Figure 14). This configuration allows for unrestricted movement of MFRs, while fulfilling the requirements outlined by end users. These wearable devices will ensure all physiological data is collected from MFRs which is crucial for the activity recording for the exercise debriefing. The following procedure must be followed to ensure the correct data acquisition: a) Turning on the wearable and prepare for acquisition, b) attaching the devices on the skin with electrodes at fixed positions or mounting it with a strap belt, c) connecting the sensors to the MR training system.

Figure 14: CardioBAN and edaBAN wearables.

The connection is made via Bluetooth with the operator station running the MED1stMR Biosignals SW Client that manages the connection and process the raw data coming in from the wearables, the data processed is, heart rate (HR), heart rate variability (HRV) and stress score. In Figure 15 the user interface is shown to establish the sensor connections to the four cardioBAN and edaBAN wearables. The baseline measurement is carried out via this user interface and the recording is started.
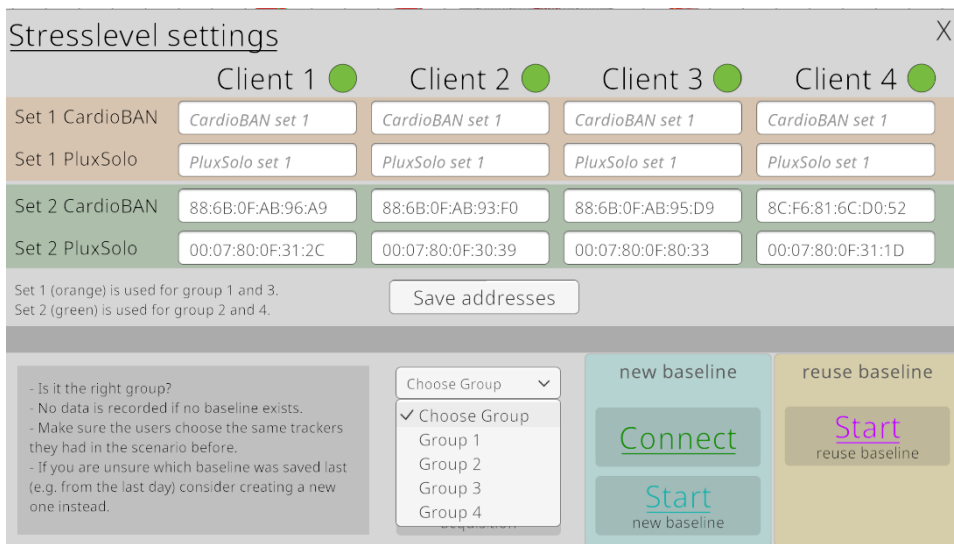
Figure 15: GUI for biosignal sensor connection and baseline measurement.

2.6 Trainee Interactions

MR interactions transform medical training, enabling trainees to practice vital life-saving techniques in a dynamic and immersive environment. In the scenarios, trainees can seamlessly check a patient's pulse and breathing rate virtually from NPCs and physically from the manikin, assess strong bleeding, and apply triage cards and tourniquets virtually. Each trainee is equipped with triage cards and a tourniquet on the upper arms as shown in Figure 15.
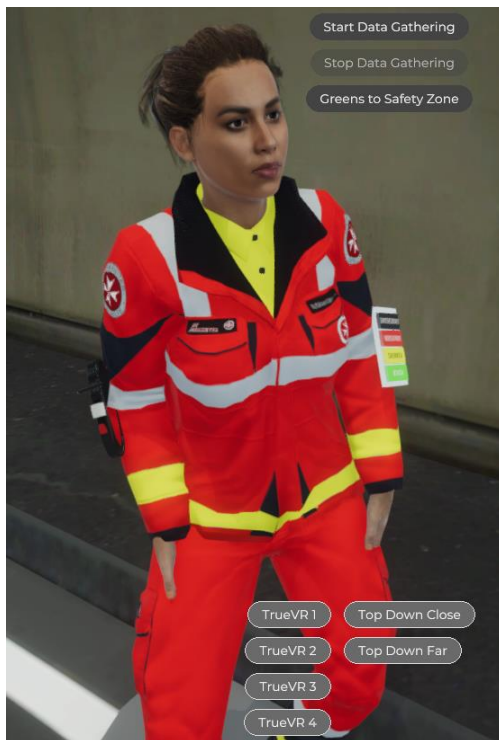
Figure 16: Trainee in virtual reality (VR) with visible application tools on the arms (triage card on left arm & tourniquet on the right arm).

The forthcoming chapters will detail the virtual assessment of patient vital signs, including pulse and respiration, as well as the simulation of physical interactions with manikins and the implementation of triage cards and tourniquets in immersive training scenarios.

2.6.1 Checking pulse

Trainees can use their hand tracking to approach the virtual patient and place their fingers on designated pulse points, such as the wrist or neck. Then a window with the pulse is shown to the trainee (Figure 17).
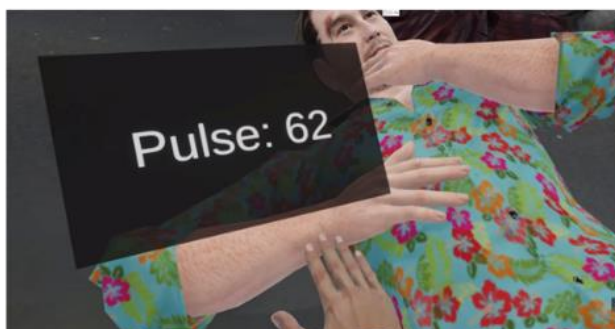
Figure 17: Checking pulse of a victim.

2.6.2 Checking respiration

For checking respiration, trainees can observe the patient's chest rise and fall animation to determine the breathing rate, check the mouth and listen to breathing sounds, within the virtual environment.

2.6.3 Physical manikin interactions

On the physical manikin trainees will feel haptic feedback, simulating the sensation of a real pulse on the wrist and neck. Simultaneously, they can feel the patient's chest rise and fall to determine the breathing rate, all within the virtual environment.

Figure 18: The Adam-X manikins used in the MR training system equipped with tracking devices (left).

2.6.4 Triage card

Trainees are provided with virtual triage cards and can select and apply them to the patients according to their condition and severity. This interactive process helps them prioritize treatment and allocate resources effectively. The following Figure 19 describes the interaction steps. First move the right hand to the left shoulder and a triage card will be held in the hand. Then hold the left hand on the colour to choose and the other colours beneath the chosen colour will disappear, in this case green and yellow. Finally place the triage card at the chest of the patient.

Figure 19: Virtual interactions to apply a triage card.

2.6.5 Tourniquet

Trainees also equipped with a virtual tourniquet to practice applying tourniquets accurately. The interaction steps are shown in Figure 20. Move the left hand to the right shoulder and the tourniquet appears in the left hand. Then place the tourniquet on the limbs (arms or legs).

Figure 20: Virtual interactions to apply a tourniquet.

3 Training Content Creation

The creation of training content for the MR training involves close collaboration between medical experts, trainers, designers, developers, and content creators. This synergy ensures that the content is accurate, relevant, and aligned with the desired learning outcomes. The success of any training system depends on user adoption. A user-friendly scenario editor for creating training content encourages more users to adopt the technology, leading to a broader and more successful implementation within an organization or first responder domain. Therefore, the scenario editor of MED1stMR is an easy-to-use application like a house builder with drag and drop functionality. The application is commanded by keyboard and mouse den described in the following.

3.1 Scenario Editor

The following text provides a brief description of the scenario editor. With this tool, you can create a virtual world specifically designed for training purposes. The process of creation is straightforward: Simply select the desired type of element from the menu and drag and drop it onto the virtual terrain. Elements like can then be adjusted in length according to your preferences, forming the building's layout. Once the layout is complete, you can place objects by dragging and dropping them onto the virtual terrain and using arrows to position them accurately (Figure 23). Circular spheres allow you to adjust the objects' orientation to your needs (Figure 24). A wide range of objects is available to create an incident site. Additionally, various types of NPCs, such as perpetrators or injured individuals can be placed on the ground.

Two perspectives are available to edit the virtual world from different viewpoints: the "Top-View" (Figure 21) provides an elevated position to observe the entire world.

Figure 21: Scenario editor with top-view, white rectangle around victims indicates walkable area in the MR system.

The freely movable camera allows you to explore the virtual environment from different angles. Once the virtual world is created, you can save it at any time and revisit it for further editing or utilize it for training purposes once it is finalized (Figure 22).

Figure 22: Scenario editor with view free camera view.

The scenario editor facilitates easy manipulation of objects in the virtual environment through virtual handles on the X, Y, and Z axes, enabling precise movement (Figure 23) and rotation (Figure 24) with intuitive gestures.

Figure 23: Positioning virtual object by handles for x-, y- and z-axis.

Figure 24: Adjustment of the alignment virtual object with handles for rotation.

The scenario editor is built in a way that the logic or intelligence is on the object that we integrate. That can be a vehicle such as a bus or a car or building objects such as doors and windows or an NPC. On these objects we can integrate injuries that have to be assessed and/or treated according to specifications of the end users to succeed or fail in the training.

The easy-to-use scenario editor is vital for the MED1stMR training system. It allows customization of content, rapid development, and adaptability for non-technical users. The reduced learning curve saves time for trainers, while iterative improvements enhance user experiences. Multimedia integration enriches learning. The editor also leads to cost savings in training development. Overall, its role in customization, efficiency, and user-friendliness ensures widespread adoption, contributing to successful training outcomes and organizational success.

3.2 Training Scenarios

Two MR scenarios that have been developed based on the requirements D2.2 and guidelines and inputs for trainings scenarios D2.3. The two scenarios have the same training goals and learning objectives.

Overarching training goals

✓ To be better prepared to handle (first) triage at the scene of a mass casualty incident.

✓ To contribute to the development of the technical system and the overall training design.

Learning objectives

Based on what emerged from the needs analysis conducted in WP2 regarding the needs and requirements of end-user organizations for mass casualty incident (MCI) training and the possibilities and limitations of the Med1stMR training system, the following learning objectives have been created:

After the training, the trainees are able to ...

1. <u>Organize</u> and coordinate the work at the scene of the mass casualty incident
2. Perform a <u>timely and correct triage</u> (based on algorithm used) of MR patient (manikin) and proper use of triage card/color
3. Identify the patient's vital parameters and decide on and demonstrate the <u>correct actions and prioritizations</u> based on triage algorithm used
4. Use <u>purposeful communication</u> with triage commander, team members, and injured people
5. Perform a <u>continuous risk assessment</u>

Trainees will be tasked with assessing the scene, triaging victims based on their injuries (consciousness, pulse, breath rate, strong bleeding), and providing appropriate medical attention. They will also need to coordinate within the team and demonstrate effective communication and teamwork skills to manage the situation successfully. Once they have triaged all, one person will give a handover to the triage commander (played verbally by the trainer), with the following information:

1. How many injured people in total?
2. How many people of which category?
3. What rescue resources do you still need now to adequately care for all patients?
4. How would you proceed further?

After the communication of this information the training ends. In the following the two scenarios, a bus crash on a country road and in a tunnel are described.

3.2.1 Scenario 1 – Country Road Bus Crash

The first scenario is a bus crash MCI which was chosen as it was frequently mentioned as relevant by end users (see D2.2) and in the literature. Furthermore, it allows all relevant learning objectives to be trained and focuses mainly on MFRs. In this training scenario, trainees will face a simulated bus crash incident with approximately 20 victims. The location is a country road, and the scenario takes place on the day and time of the actual trial, adding an element of realism. The weather conditions on the scene are cloudy, with no rain. To enhance the immersion, sound effects of environmental noises recreate the atmosphere of an actual accident site. The scenario includes a life-size virtual bus and the rescue services have already assessed the intervention zone as safe, and traffic on the road has come to a complete stop to ensure the safety of the trainees and the overall experience.

Figure 25: Scenario 1 – country road bus crash (top view in the exercise control).

The scenario is designed to challenge trainees to make critical decisions under pressure, assess risks, and prioritize their actions to save lives efficiently.

3.2.2 Scenario 2 – Tunnel Accident

In this training scenario, trainees will be immersed in a simulated bus crash incident that occurred in a tunnel (Figure 26). The visuals and sound effects accurately depict the accident site, including environmental sounds that create a sense of urgency and characteristic of a tunnel setting. Trainees will face the complexities of rescuing victims and managing resources effectively within the confined space of the tunnel. It is worth mentioning that a tunnel scenario also demonstrates very well how easy it is to train in environments that are otherwise difficult to make available for training, as they would have to be closed off separately.
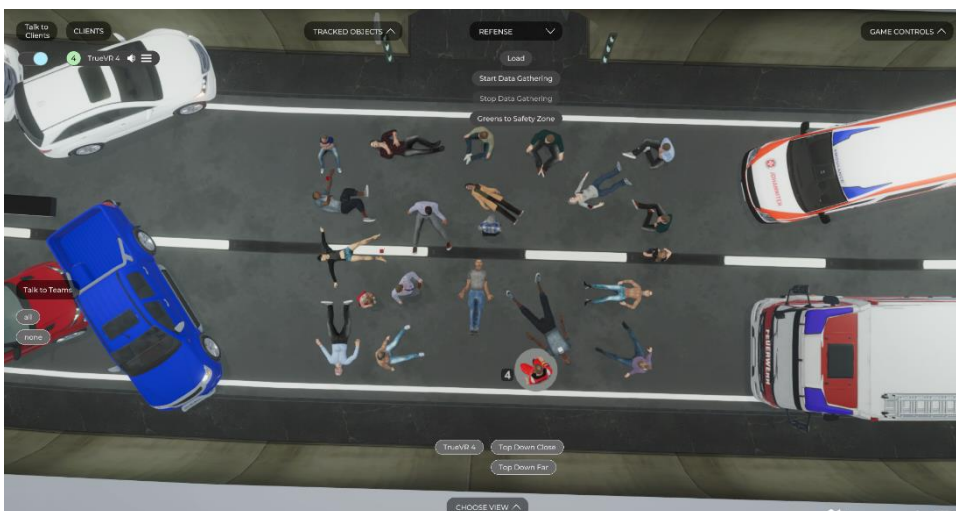

Figure 26: Scenario 2 – bus crash in a tunnel (top view).

4 Debriefing

Introducing the MED1stMR debriefing system – two innovative and user-friendly tools were designed to enhance the training experience: a) the MR after action review solution capturing every crucial moment in detail and b) the MED1stMR Analytics and Statistics (MAS) Tool to provide metrics and indicators of the trainees' performance. These two tools are described in detail in the following chapters.

4.1 MR after action review solution

The MR after action review solution allows instructors and trainees to review and analyse their performance and feedback after the mixed reality training session in the 3D scenario environment. With a simple initiation process, just load the replay file using the "load" button, and the trainer will be ready to start a comprehensive analysis.

The interactive interface (Figure 27) allows to engage with patients and closely monitor vital signs, including heart rate, breathing frequency, and expected triage outcomes of patients, by selecting a patient in the scene. Navigating through the recording is effortless with the intuitive timeline interface. Users can seamlessly scroll through the timeline to locate specific moments of interest, allowing for precise playback control and efficient review of recorded content.

Figure 27: GUI for after action review.

The state-of-the-art "Bender" camera smoothly glides through the simulated environment, offering multiple perspectives for a more profound review. Navigating the system is done with intuitive keyboard and mouse controls. Zoom in effortlessly using the "w" key, zoom out with "s," and fluidly move left and right with the "a" and "d" keys. Furthermore, adjusting the camera angle is as easy as holding the right mouse button. Different views are shown in Figure 28.

Figure 28: Different views with the debriefing system.

At its core, the Debriefing System aims to deliver valuable insights, foster professional growth, and empower you to effectively refine your skills. Embrace the endless possibilities it offers and maximize your simulation training with ease.

4.2 Analysis and Statistic tool

The MED1stMR analysis and statistic (MAS) tool is a web-based dashboard that displays various metrics and indicators of the trainees' performance. It provides access to the following training performance metrics visualized on a dashboard for the trainer and the trainee. The trainer area allows them to see all their assigned trainees' data and metrics by selecting one of the trainees, while the trainee view shows only the own training sessions on a dashboard. The dashboard view is shown in Figure 29 and Figure 30 showing the parts scrolled down in the dashboard and described in the following:

- Total Triages reflects the sum of triage processes executed.

- Minimum, Maximum and Average Triage Duration (s) portrays the shortest, longest and mean time, respectively, taken for triage processes.

- Triage Accuracy assesses the precision in identifying pre-assigned colours of NPCs and aims to gauge simulation clarity over trainee performance.

- Total Training Time denotes the entire duration spent in the scenario.

- Identified Stressors table delineates high-stress periods with details like timestamps, anomaly confidence and severity, identified stressor and stressor confidence, which evaluate the certainty and significance of stress alterations and their causes.

- Main Stressor highlights the primary source of severe stress.

- Stress during training quantifies stress levels at each second, derived from heart rate and heart rate variability versus baseline measurements.
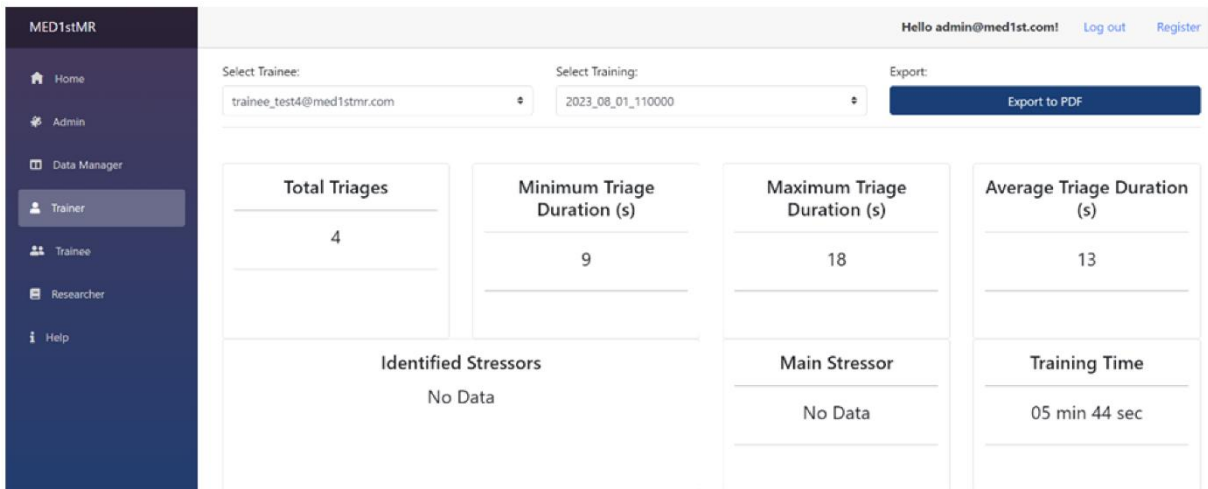
Figure 29: MAS tool UI for the trainer showing triage training metrics.

Figure 30: MAS tool UI for the trainer showing diagrams for triage accuracy and stress curve over the training.

The MAS tool is a key component for next-generation MR training systems and encapsulates machine learning model development and data processing pipelines within the MED1stMR framework, fostering an advanced, adaptive environment.

5 Summary

The advancement of the Mixed Reality Training Environment following six field trials shows a remarkable leap forward in immersive training methodologies. The MED1stMR system seamlessly merges virtual and real patient simulation manikins, offering a distinctive and captivating learning experience that empowers learners to acquire skills and knowledge with unparalleled effectiveness.

Beyond mere simulation, our training scenarios immerse emergency responders in lifelike incidents featuring multiple victims, authentic environmental factors, and potential hazards. This exposure enables trainees to hone critical skills, refine decision-making capabilities, and enhance coordination and communication in high-pressure emergency situations. Through interactive interactions with non-player characters (NPCs) and real manikins, trainees gain invaluable hands-on experience in a risk-free environment. The scenario editor provides users with a versatile platform to create, customize, and fine-tune training scenarios according to specific learning objectives and requirements.

Moreover, our system incorporates innovative features for stress assessment in real-time through biosignal measurement. By monitoring physiological responses such as heart rate variability and galvanic skin response, trainers receive immediate feedback on trainees' stress levels during simulated scenarios. Leveraging advanced algorithms these sensors translate raw physiological signals into actionable insights, facilitating a comprehensive understanding of the trainee's stress dynamics throughout the training session.

Furthermore, our solution introduces an innovative debriefing tool featuring a 3D after-action review and enhanced analysis and statistic capabilities. This debriefing tool allows trainers to conduct comprehensive post-training assessments, facilitating in-depth analysis of trainees' performance, identifying areas for improvement, and fostering continuous learning and development.

In summary, the MED1stMR demonstration tool offers an immersive and engaging training experience underscored by extensive positive feedback from six field trials with over 250 trainees, that raises the bar for medical education, ultimately leading to improved patient outcomes and enhanced readiness for emergency response in mass casualty incidents.