D3.6

European Framework for Training and Assessment (using MR) of EPME Behaviour of Medical First Responder Professionals

Version
V1.0

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Versions

Version	Date	Author(s)	Description
V0.1	16/08/2023	Helmut Schrom-Feiertag (AIT)	First Draft
V0.2	21/09/2023	Vendula Rajdlova (AIT) Olivia Zechner (AIT) Jakob Uhl (AIT) Ottilie Marie Frenkel (HFU) Matthias Beutel (UHEI) Lina Gyllencreutz (UMU) David Sjöberg (UMU) Eva Pelgen (JOIN)	Input MR training, assessment, EPME model, target audience, training concepts and goals, requirements, training framework, relevant perspectives
V0.3	25/09/2023	All research partners	Input to corresponding parts.
V0.4	27/09/2023	Helmut Schrom-Feiertag (AIT)	Finalisation of the document.
V1.0	29/09/2023	Helmut Schrom-Feiertag (AIT) Vendula Rajdlova (AIT)	Final formatting and upload.

Report Review

Version	Date	Reviewer(s)	Statement
V0.3	25/09/2023	All research partners	Own parts complete, minor additions necessary.
V0.4	28/09/2023	Helmut Schrom-Feiertag (AIT) Vendula Rajdlova (AIT)	Report ok.

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29.09.2023

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29.09.2023

List of Acronyms and Abbreviations

Acronym/ Abbreviation	
AI	Artificial Inteligence
CPM	Civil Protection Mechanism
EDA	Electrodermal Activity
ECG	Eectrocardiogram
EPME	Effective Performance in Medical Emergencies
EUO	End User Organization
EU MODEX	EU Module Exercises
GUI	Graphical User Interface
HR	Heart Rate
HRV	Heart Rate Variability
MCI	Mass Casualty Incident
MFR	Medical First Responder
MR	Mixed Reality
SCL	Skin Conductance Level
SCR	Skin Conductance Response
VR	Virtual Reality

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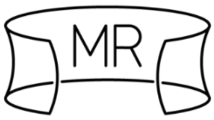
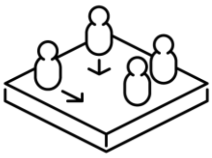
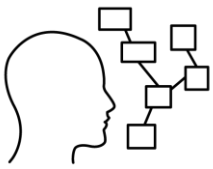
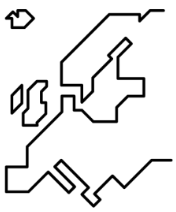
Relation to Objectives

Objective	Description
	**Obj. 1: Pioneering MR training approach for enhanced realism** The mixed reality framework is directly aligned with Obj. 1. The MR training framework provides the conceptual and technological foundation for achieving enhanced realism in training.
	**Obj. 2: Effective training scenarios and a training curriculum** The MR training framework describes the fundamentals for heightened level of realism that enhances the effectiveness of the training, as it allows trainees to practice skills and decision-making in contexts that closely mirror real-world situations. The depicted MR training assessment provides a basis to evaluate the training outcome and form the basis for the implementation in a training curriculum.
	**Obj. 3: Physiological signal and trainee behaviour feedback loop and smart scenario control** The MR framework is instrumental in achieving this objective by presenting the technological approach necessary for monitoring physiological signals and trainee behaviour, as well as enabling smart scenario control. This integration of real-time feedback and dynamic scenario adjustments enhances the effectiveness and adaptability of the training program.
	**Obj. 4: Position the pioneering MR training approach across Europe** This deliverable provides guidelines using MR for MCI training in a harmonized way and offers a way to bridge gaps in training methodologies across member states as a tool to unify medical first responder training practices, promoting consistency and quality.

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Executive Summary

This deliverable D3.6 "European Framework for Mixed Reality Training and Assessment of Effective Performance in Medical Emergencies of Medical First Responder Professionals" focuses on the European scale of the innovative MED1stMR project.

At a time when emergency healthcare is critical and medical emergencies are an ever-increasing challenge, experts and professionals from European institutions in research, development and emergency medical services have worked closely together in MED1stMR to develop a ground-breaking training framework that uses the latest mixed reality (MR) technologies to revolutionise the training and assessment of medical first responders. This project not only has the potential to significantly improve the decision making, skills and efficiency of first responder professionals, but also to improve the safety and well-being of communities across Europe.

This report provides an in-depth analysis of various aspects of MR training. It explains in detail the objectives, scope and importance of the European Framework for Mixed Reality Training and Assessment in Medical Emergencies. It also highlights the specific components and content of this framework and explore how it can support medical first responder professionals across Europe in a better preparation for medical emergencies.

This framework aims to establish common standards, guidelines and best practices for the training and assessment of MFRs in medical emergencies, particularly in situations where rapid medical assistance is required and resources are limited, necessitating effective triaging. This will describe the use of MR technologies that combine virtual and real objects to create realistic training environments for medical first responders. These environments use headsets, tracking technologies, 3D models and other digital tools to simulate realistic scenarios.

In addition to training, this framework places a strong focus on assessing the performance of MFRs. Performance assessment plays a critical role in monitoring the decision making, skills and knowledge of first responders to ensure that they can respond effectively in emergency situations.

The aim of this report is not only to deepen the understanding of this ground-breaking project, but also to highlight its potential impact on emergency care and the safety of citizens in Europe.

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 Point of View: Requirements Report, Stakeholder Map and Expectation Summary for Smart Wearables, MR Training Framework and Curriculum	In this deliverable the fundamental outcomes from the requirements analysis are documented and build the basis for this deliverable.

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D2.3	Guidelines and Inputs for the future Training Scenarios	This deliverable provides a guideline and template to define training scenarios based on selected training objectives.
D3.1	Overview of Current Training and Best Practices of Training Curricula in European Medical First Responders and Impacts on the EPME Modell and Training	The MR framework and assessment is aligned with current and best training practices from European medical first responders.
D3.2	Multi-Dimensional Conceptual EPME Model and Research Agenda for Validation	Empirical connection between the physiological responses, the psychological experience, and the behavioural output. Provides the base understanding on stress and decision and supports the creation of optimized scenarios.
D3.3	Concept for Physiological Measurement Suite for Stress Assessment	Describes the basics for real-time stress measurement during MR training.
D3.4	Real-Time Training Progress Assessment Tool	Basis for the stress assessment in the training dashboard and smart scenario control. An essential part of the MR training framework for personalized and optimized training.
D3.5	Aggregate team performance assessment model	MR training assessment includes also performance indicators describing team performance and is considered in the MR training framework.
D4.3	Activity Recording for the Exercise Debriefing	An essential part is activity recording for the feedback to the trainees and guidance of the trainer during the training and in the debriefing.
D4.4	Physiological signals Acquisition Hardware and Software Framework	An essential part closing the feedback loop with biosignals measurements for real-time stress assessment and smart scenario control.

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

No.	Title	Basis for
D6.5	MED1stMR Final Evaluated VR Training Scenarios	The evaluation of the scenarios will be built on the assessment proposed in this deliverable.
D6.6	MED1stMR Final Guidelines for VR Training	The described framework will be further enhanced into concrete guidelines for the implementation of the training.
D6.7	MED1stMR Final Training Curriculum for EPME	The framework builds the basis and the evaluation results from the field trial will be used to define a

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		final training curriculum for effective performance in medical emergencies.
D7.1	Concluding reflection and knowledge of the technologies in relation to the different emergency scenarios	The framework described is used for the implementation of the MR training in the field trials and will be evaluated. Results will be included in this deliverable.
D7.2	Implementation concept of MR training by end users	A concrete concept of MR training will be developed based on the framework and assessment provided in this deliverable.

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1 Introduction

Mixed reality (MR) is a technology that combines the real and the virtual worlds, allowing users to interact with both physical and digital objects. MR provide immersive and engaging learning experiences that can enhance the skills and knowledge of trainees in various domains. There are different ways to design a training with MR, depending on the learning objectives, the target audience, the available resources, and the evaluation methods. In the context of this document, for immersive MR training environments, two key concepts are essential to understand: MR training framework and MR training assessment.

- A **MR training framework** describes the system that provides trainees with realistic and engaging scenarios to practice and improve their skills, while also providing feedback and evaluation of their performance.
- **MR assessment** is a process that measures the learners' abilities and outcomes using MR-based task performance and metrics.

The described MR training framework and assessment for medical first responders (MFRs) form a system that uses mixed reality technology to simulate Mass Casualty Incident (MCI) and provide realistic and effective training and evaluation for MFRs. MCIs are incidents where the **available resources are insufficient for the immediate need for adequate medical care**. MCIs are thus incidents which produce so many casualties and are so extensive or demanding that resources must be organised, managed, and used in a particular way to maintain an adequate level of care.

Therefore, the MED1stMR training framework for MFRs addresses following key elements:

1. **Objectives and Outcomes**: Enhancing situational awareness, resilience, and MCI performance.
2. **Audience Proficiency**: Tailoring to MFRs' experience levels.
3. **Scenario and Tasks**: Defining MCI specifics and required actions.
4. **Technology and Devices**: Selecting virtual environment, patient simulation manikin, feedback systems, and sensors.
5. **Feedback and Guidance**: Providing real-time cues and post-training assessment.
6. **Evaluation Metrics**: Assessing performance, cognitive states, and satisfaction.

The MR assessment for MFRs is a process that measures the MFRs' abilities and outcomes using MR-based tasks and metrics. MR assessment for MFRs should consider the following aspects:

1. **Validity and Reliability**: Ensuring the assessment accurately measures intended criteria and produces consistent, accurate results.
2. **Feasibility and Usability**: Addressing factors like availability, accessibility, affordability, and user satisfaction for both MFRs and instructors.
3. **Ethical and Legal Concerns**: Managing issues related to privacy, security, data ownership, and debriefing processes associated with the assessment.

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These aspects collectively shape the effectiveness and integrity of MR training implementation and assessments for MFRs.

2 Current processes and limitations in MCI training

The aggregated analysis of the requirements provided the results that highlight the significant challenges that medical first responders (MFRs) have identified in relation to current training for MCI scenarios. Through a comprehensive synthesis of data obtained from extensive co-creation workshops, interviews and training observations, it becomes evident that MFRs have identified and emphasized existing shortcomings within the area of MCI scenario training.

Interviews conducted with both MFRs and trainers have yielded insights that revolve around two critical areas of limitations. These limitations have played a pivotal role in shaping the formulation of a training framework based on MR technology. The framework's development has been closely aligned with the specific needs and demands articulated by the end-users.

First and foremost, MFRs have observed that the current training for MCI scenarios **lacks a sufficient level of realism**. This perception of limited realism encompasses multiple facets within the current training exercises. For instance, there is ***a deficiency in incorporating environmental hazards*** that are typically present at an actual incident scene. This omission hampers MFRs' ability to effectively assess risks in such scenarios, a crucial skill in emergency medical care. Additionally, the ***portrayal of casualties*** in training often falls short of realism. While some training programs involve actors playing the roles of casualties, these actors struggle to accurately convey physiological and emotional responses to MFRs' actions. Moreover, ***the number of casualties depicted*** in training is usually limited, which contrasts starkly with real-world MCIs where multiple casualties are the norm.

Secondly, both MFR trainer and trainees have raised concerns regarding **the evaluation process** after MCI scenario training sessions. As indicated in the findings from the requirements phase, there is a general absence of structured post-training evaluation following the completion of MCI scenario training. When implemented, MFRs often perceive post-training evaluations as rushed, lacking sufficient time to assess both team and individual training performance in depth. The complexity of ***assessing the actions*** of numerous trainees simultaneously during real-world MCI scenario training poses a challenge for trainers. This results in post-training evaluations that lack depth whilst also failing to provide individualized feedback. Additionally, due to time constraints inherent in conducting large-scale training exercises, it's not feasible to halt the progression of a live scenario for real-time feedback.

These findings underscore that the identified limitations create a disparity between the current approach to MCI training and the intricate nature of actual large-scale disaster incidents. Addressing these disparities becomes pivotal in elevating the disaster preparedness level among MFRs.

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3 Effective performance in medical emergencies

One fundamental component of the MED1stMR training framework involves the integration of a sophisticated model that delineates human factors pertinent to stress responses and explains their profound influence on critical cognitive functions such as attention allocation, decision-making processes, and subsequent actions.

This model for effective performance in medical emergencies (EPME) serves as a fundament for comprehending and replicating the intricate interplay between stress-induced physiological reactions and cognitive performance, providing an invaluable training tool for enhancing the preparedness and effectiveness of medical first responders in the face of challenging and demanding real-world scenarios. Through this MR-based training approach, trainees are afforded a comprehensive experiential learning environment, which not only exposes them to the multifaceted challenges of mass casualty incidents but also equips them with the requisite skills to navigate and mitigate the impact of stress on their professional decision-making capabilities.

As a causal chain model, the EPME model, shown in Figure 1, explains how stress can influence the core components, namely attention, decision-making, and action. This chain is influenced by an interaction of three elements that are categorised as human factors, stress response, and extra effort.

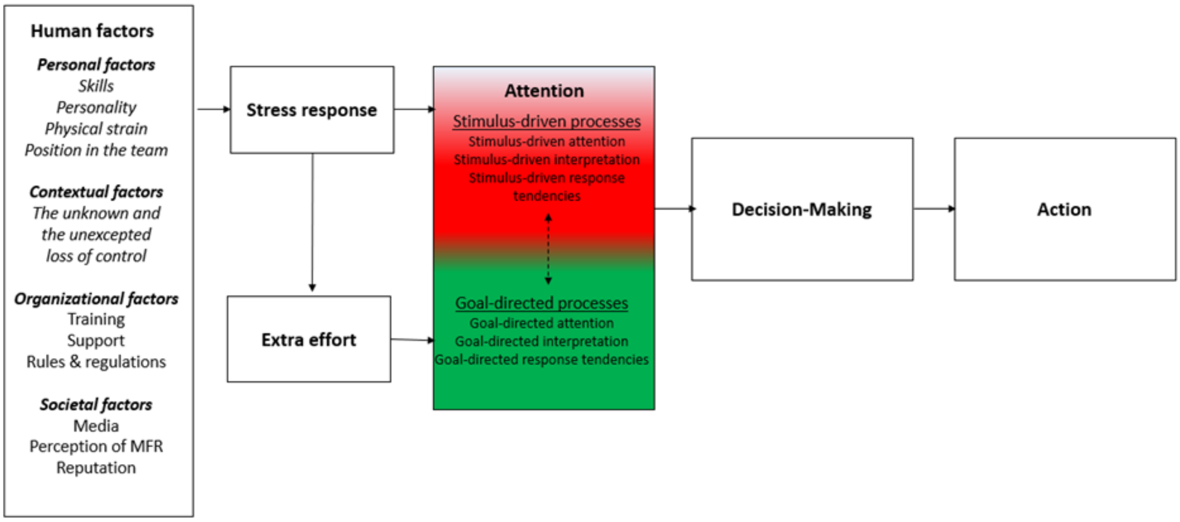

Figure 2: The EPME model describes the interrelations how stress in medical emergencies affects attention, decision-making, and action through a causal chain.

Human factors represent an array of coping resources that influence an individual's perception of stressors and their stress response. First, they include personal factors such as personality traits, skills and physical characteristics that tend to be stable although they might be trainable to some extent (e.g., stress regulation techniques). Second, contextual factors such as the dimension of the incident, patient demographic, and the experience of the team. Third, organisational factors representing administrative influences on the MFRs (e.g., training, guidelines). Fourth, societal factors such as the public image of MFRs that may have influence on their confidence or the patients' response.

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The *stress response* is traditionally conceptualised as a dynamic process that includes three main phases (Seeman & Robbins, 1994). The initial phase is characterised as a resting state. After exposures to a potentially threatening stimulus (i.e., stressor) the reactivity phase is reflected on multiple psycho-physiological and behavioural levels and can be differentiated into an immediate (e.g., cardiovascular reactions, stress related emotions, fight-or-flight behaviour) and a delayed response (e.g., hormonal changes). An individual's reactivity captures the intensity of the stress reactions followed by the recovery phase in which an individual returns to the previous resting state. Further, an anticipation phase is discussed as an additional phase that precedes the stressor exposure and shows initial levels of reactivity (Luong et al., 2018).

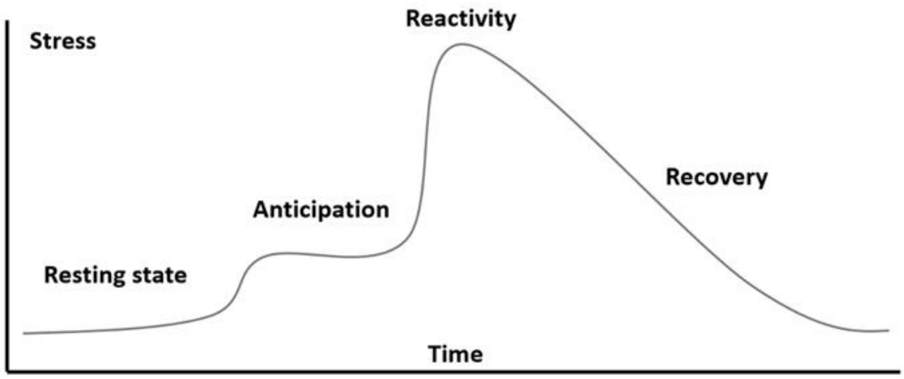

Figure 3: Visualisation of the different sequences within the temporal stress process.

The stress response is elicited in an automatic, uncontrollable manner with potentially adverse effects. However, these can be combated with intentional behavioural changes that are included in the EPME model as extra effort. The compensatory effects of extra effort may be achieved by reducing stress directly or maintaining goal-directed behaviour and suppressing impulsive actions (Eysenck et al., 2007; Nieuwenhuys & Oudejans, 2017). However, identifying and allocating available resources is a crucial factor in combating the negative impact of stress as extra effort surpasses mere additional spending of mental capacity (Frenkel et al., 2022).

Regarding attention, the model distinguishes between two types of processes. While stimulus-driven processes reflect reactions to the immediate environment and are mainly driven by external forces, goal-directed processes are guided by predefined plans and are fostered by the individual itself (Corbetta et al., 2008). Both processes have their distinct way in guiding attention and information processing and thereby influencing the resulting behaviour. Thus, stimulus-driven attention leads to ad hoc decision-making based on options presented in the immediate environment. In contrast, goal-directed attention allows for the perception of options according to a predefined plan of actions. The execution of the decision is reflected by the action part in the model. It can be adversely influenced by stress directly (e.g. disruption in motor patterns) and indirectly via limitation of options mediated by changes in attention and decision-making processes.

In general, interventions can help to combat the potentially negative effects of stress at several steps in the model. They can be aimed at increasing perceived coping resources, enhancing effective

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implementation of extra effort, or applying psychological skills training (e.g., self-regulation strategies) to redirect attention or buffer immediate physiological responses. With the EPME model we can establish the precise link between stress, attention, decision-making, and behaviour and helps to optimize the feedback loop to detect what causes stress in the trainees and what may actually help them to reach optimal arousal levels for performance.

4 Framework for MR Training

The MR Training Framework aims to harmonize and enhance the training and assessment of medical first responders across Europe. Rooted in the training concepts and goals discussed in the requirements phase with all of our end user organisations in the project, this framework addresses critical questions such as the core objectives of MCI training using MR and its unique advantages over existing MCI training programs. Recognizing that MR technology encompasses a broad spectrum of tools and methodologies, our framework offers flexibility in implementation while ensuring rigor and effectiveness. The framework is composed of several key training modules, including patient simulators, stress measurement, skills training, smart scenario control, and debriefing mechanisms. These modules work in synergy to offer a holistic training experience, addressing both technical skills and psychological resilience, thereby filling the gaps in current training paradigms.

In the context of training MFRs for high-stress scenarios in mass casualty incidents, the application of MR technology plays an essential role. MR is employed to simulate realistic situations, incorporating elements designed to induce stress in trainees. Therefore, the MED1stMR MR training framework for MFRs consider the following aspects:

- The learning objectives and outcomes of the training, such as improving the MFRs' situational awareness, resilience, and performance in MCIs.
- The target audience and their prior knowledge and skills, such as the level of experience and expertise of the MFRs.
- The scenario and the tasks to be performed in the training, such as the type, location, and severity of the MCI, and the actions and decisions required by the MFRs.
- The MR technology and the devices to be used for the training, such as the type and quality of the virtual environment, the haptic feedback, and the wearable sensors.
- The feedback and guidance to be provided to the MFRs during and after the training, such as the verbal, visual, or auditory cues, the performance scores, and the debriefing sessions.
- The metrics and parameters to be used to evaluate the MFRs' performance, cognitive and emotional states, and satisfaction, such as the accuracy, speed, and quality of the MFRs' actions, the physiological and behavioural data, and the subjective ratings.

Which are described in detail in the following sections.

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4.1 Learning objectives

The results from the requirements analysis showed that learning objectives in the context of MCI scenario training encompass a range of critically important skills and competencies necessary for MFRs to provide effective response and management in MCIs. The learning objectives emphasize the importance of communication, coordination, and adaptability in handling complex emergency situations. These learning objectives can be grouped into the categories on strategic and executive level with the corresponding abilities.

4.1.1 Strategic level (incident commander)

At the strategic level, learning objectives can be divided into the following categories and activities.

Initial Scene Assessment and Communication

- Identify yourself as a commander.
- Conduct a scene safety assessment to ensure the safety of yourself and others.
- Establish internal and external communication channels.
- Coordinate with internal and external teams effectively.
- Organize and categorize the scene into zones (hot, warm, cold) for efficient response.
- Make informed decisions based on the initial assessment and reiterate scene safety assessment to adapt to changing circumstances.

Triage and Evacuation

- Arrange and perform the first triage to assess the severity of injuries.
- Assign evacuation priority to the triaged victims based on their condition.
- Continue communication and coordination with internal and external teams.
- Make ongoing decisions regarding the prioritization of care and evacuation.

Logistics and Resource Management

- Organize the logistics of care and transport for uninjured individuals.
- Coordinate internally and externally to efficiently manage resources.
- Communicate the arrival of additional resources and maintain records.
- Identify access and egress points to the incident site, oversee the parking of ambulances for optimal access.
- Determine the correct hospital destination and choose the appropriate transport mode for each patient.
- Continuously make decisions to adapt to resource availability and patient needs

4.1.2 Executing level (executing MFR)

On the executing level the learning objectives comprises the following category.

Performing triage

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- Rapidly evaluate and categorize injured individuals based on the severity of their injuries.
- Use of triage tags.
- Communicate crucial information to triage commander.
- Performing systematic assessment (ABCDE) and treatment.
- Communication with commander to evacuate victims.
- Performing psychological first aid identifies patients who worsen and report to the appropriate commander for treatment.
- Effectively utilize uninjured individuals as resources.

By mastering the technical and non-technical skills outlined in the learning objectives, MFRs will be well-prepared to respond effectively and efficiently in high-pressure, complex disaster situations. Effective communication, swift decision-making, and thorough patient assessment are at the core of this comprehensive training program.

4.2 Target audience

The target audience for MR training MCIs would primarily be:

1. **Medical First Responders (MFRs):** This includes paramedics, emergency medical technicians (EMTs), nurses, physicians, and other healthcare professionals who are the first to arrive at the scene of a mass casualty incident.
2. **Emergency Response Personnel:** This may extend to include firefighters, police officers, and other emergency services personnel who work alongside MFRs in MCIs.
3. **Medical Training Institutions:** Institutions that provide training and education for MFRs may use mixed reality training as a component of their curriculum.
4. **Medical and Emergency Services Organizations:** Organizations responsible for coordinating and overseeing emergency response efforts, such as local emergency management agencies or national healthcare organizations.
5. **Healthcare Facilities:** Hospitals, clinics, and other healthcare facilities where MFRs are employed may implement mixed reality training as part of their ongoing professional development programs.
6. **Government Agencies:** Government bodies responsible for regulating and overseeing emergency response and healthcare services may adopt MR training programs to enhance preparedness for MCIs.
7. **Training and Simulation Centers:** Facilities that specialize in providing simulation-based training for healthcare and emergency response personnel may utilize MR technology for MCI training.

By targeting these groups, MR training for MCIs aims to enhance the preparedness, skills, and response capabilities of medical first responders in high-stress, critical situations.

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4.3 Scenario and tasks to be performed

This includes the scenario and the tasks to be performed in the training, such as the type, location and severity of the MCI, as well as taking the actions and making decisions required by the MFR. To address the perceived lack of realism from real MCI trainings, the current MED1stMR training system offers MFRs the opportunity to fully engage with a **dynamic training environment**. At its present state, the MED1stMR training system includes training in two distinct environments, both centred around traffic incidents. One of these environments simulates an urban setting, presenting MFRs with a bus crash scenario involving passengers of diverse ages and genders. The other environment simulates a traffic incident situated within a road tunnel.

While there is potential to incorporate dynamic surroundings, the challenge lies in **fully replicating a virtual reality** (VR) environment that allows MFRs to respond as they would in real-life situations. For example, the limitations of the current MED1stMR training system require training to be conducted within a confined 10x10 meter area. This constraint makes certain actions, like entering the crashed bus, impossible to train. As a result, all activities undertaken by MFRs must occur outside the crashed bus, thereby restricting the scope of achievable learning objectives within the training. For instance, it was highlighted that MFRs desired the ability to survey the situation and assess the safety of the incident. For MFRs to achieve learning objectives related to incident site risk assessment and management, the VR environment must be dynamic. One such example would be the inclusion of firefighters in the training scenario. This would increase complexity by having the firefighters retrieve casualties from areas inaccessible MFRs. Furthermore, including bystanders at the incident scene replicate a real-world situation and add an extra layer of risk assessment to the training scenario.

Within the context of realism, **avatars** representing casualties can be customized not only in terms of physical attributes but also to accurately portray the type of injuries sustained during the incident. Unlike human actors, digital avatars possess the capacity to respond without the constraints of human limitations. For instance, conveying sensations like breathlessness or loss of consciousness proves immensely challenging for human actors to replicate convincingly, especially in a manner that mimics real-life scenarios. By utilizing avatars capable of responding more authentically and reflecting the **progression of injuries**, MFRs can engage in training experiences that closely simulate real-world incidents, thereby enhancing the fidelity of the training curriculum.

Despite these advancements, it's important to acknowledge the need for ongoing development. One of ongoing development areas involves the **integration of physical objects** into the VR environment e.g. the elements that constitute MR. The primary goal of this framework is to prepare individuals for responding to MCIs. This involves triaging injured individuals by evaluating their ability to follow instructions, their airway, breathing, pulse, and controlling severe bleeding. All these aforementioned tasks performed by MFRs can be characterised as physically interacting with the casualties. Thus, emphasizing the importance of incorporating physical objects into the simulated training environment.

The initial critical task is to differentiate those who can walk independently from those who cannot, accomplished by having one of the MFRs call for those who can walk to come forward. Avatars

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programmed as unharmed (triage green) will respond and move to a designated area on the incident site. However, replicating realistic behaviour poses a challenge because individuals in such situations often experience fear, shock, concern for self or loved ones, a desire to help, or a need for comfort. This situation doesn't necessitate MR technology but requires various responses from the injured. Some may express pain, others may call for assistance or cry hysterically, while others may rush toward MFRs seeking help for severely injured individuals. Portraying these types of behaviours convincingly and realistically is essential, as MFRs must be able to respond appropriately, either to calm those in distress or to ask those requesting help to wait. Managing interpersonal reactions remains a persistent challenge for the current MED1stMR training system.

The current MED1stMR training system relies on **trainers**, human operators who effectively control the avatars, overseeing both their physical reactions and verbal interactions with MFRs. This implementation has proven to be difficult for both MFRs and trainers, resulting in that the avatars in the current MED1stMR training system only behave and verbally respond with pre-programmed answers that are repeated based on the programming. An upcoming innovation involves the integration of an artificial intelligence (AI)-guided system to control the avatars. This forward-looking enhancement aims to alleviate the logistical complexity associated with requiring multiple trainers, each responsible for controlling a single avatar during the training. By implementing AI guidance, the training process can be streamlined, making it more efficient and effective in preparing MFRs for real-world emergency situations.

Another objective is to **assess triage levels** based on vital signs like airway, breathing rate, pulse, and consciousness. This is achieved through physical assessments using integrated manikins in the VR environment. Trainees can feel breathing and pulse and perform jaw thrust to open airways if needed. Initially, a few vital signs determine injured individuals' priority during MCIs. Thereafter, when the serious cases are identified, advanced assessments become necessary (secondary triage). The current MED1stMR system includes MR features for initial triage learning objectives, but further development is needed for subsequent triage and treatment goals.

Two MR scenarios that have been developed based on the requirements and guidelines and inputs from end users. 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 of end-user organizations for 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:

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1. Organize and coordinate the work at the scene of the mass casualty incident.
2. Perform a timely and correct triage (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 correct actions and prioritizations based on triage algorithm used.
4. Use purposeful communication with triage commander, team members, and injured people.
5. Perform a continuous risk assessment.

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.

4.4 MR Technology and devices

In this section, we delve into the components of mixed reality (MR) technologies and devices crucial for training, encompassing aspects like the virtual environment's type and quality, haptic feedback mechanisms, and the integration of wearable sensors.

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 you make is accurately reflected in the virtual environment, allowing for natural and realistic interactions with the training scenarios. Whether practicing complex maneuvers or refining essential skills, the full body tracking ensures that your actions seamlessly translate into the virtual world.

The wireless headset 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. Each participant has the same equipment, which includes: Two hand sensors, two foot sensors, one back sensor, and a VR headset with headphones.

In terms of treatment, the challenge is **integrating MFRs' equipment into MR**, including items like tourniquets and haemostatic dressings, to meet the triage learning objective. Realistic portrayal of catastrophic bleeding is essential, with bleeding appearing severe on arrival and stopping with correct tourniquet placement. Integration of various equipment, beyond tourniquets, is crucial for training

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and enhancing the ability to manage MCIs. Advanced avatar functions are necessary for subsequent triage assessments, such as identifying punctured or blood-filled lungs through absent lung sounds or trachea displacement.

4.4.1 Scenario Editor

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.

The MED1stMR 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.

4.4.2 MR simulation

By integrating virtual and real elements into one MR simulations provide a dynamic environment for training. This technology empowers MFR trainees to interact with virtual and real objects, enhancing the depth of engagement and the potential for experiential learning. 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.

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. 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. 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. 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

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resources effectively. Trainees also equipped with a virtual tourniquet to practice applying tourniquets accurately.

Additionally, the integration of wearable sensors adds a layer of precision and interactivity, allowing for a more responsive and personalized experience.

To initiate a scenario, the VR equipment is first explained to the trainees and set up. The operator GUI (Graphical User Interface) is then launched with the selected players, and the training session begins.

4.4.3 Patient simulator

The patient simulator manikin ADAM-X enhances the immersive training experience, offering a hands-on tool for practicing skills needing tactile feedback, such as intubation or resuscitation. This manikin is a detailed replica of human skeletal and anatomical features. It reacts to treatments and displays medical data like blood pressure, heart rate, respiratory patterns, chest movements, facial and finger cyanosis, pulse, electrocardiogram, CPR metrics, and various physiological reactions like sweating and tearing. All this information is wirelessly transmitted to the VR server for immediate observation and is archived for post-training review.

4.4.4 Stress measurement module:

Determining the ideal stress level to enhance learning performance in simulation training is challenging, given that it differs among individuals. As a result, tailoring stress monitoring and scenario adjustments are crucial steps towards more individualized training.

To reliably assess a trainee's stress, a multi-biosignal measurement method was adopted. Heart rate (HR) and heart rate variability (HRV) are sourced from electrocardiogram (ECG) electrodes, either worn as belts or adhesive electrodes positioned on the upper left chest area. Additionally, Electrodermal Activity (EDA) is captured using adhesive electrodes on the trainee's back. While the hand is the preferred location for EDA electrode placement, medical first responders (MFR) require unobstructed hands for patient care and equipment handling. The EDA signal is then split into the Skin Conductance Response (SCR) - short-term changes in skin conductance due to specific stimuli, and the Skin Conductance Level (SCL) - a consistent skin conductance level unaffected by specific stimuli, indicating an individual's overall arousal state influenced by factors like anxiety or fatigue. This sensor information is then processed and sent to the MR server through the PLUX biosignals sensor system.

4.4.5 Skills Training

The Skills Training component is a critical part of the overarching Mixed Reality (MR) Training Framework designed for Medical First Responders (MFRs). This module goes beyond the conceptual understanding of medical procedures, emphasizing the importance of tactile experiences and embodied practice. As the hands serve as critical diagnostic tools for MFRs, it's essential to master the art of using them effectively. For instance, the skilful manipulation of medical tools like a valve bag involves understanding the interplay of pressure, timing, and positioning, all of which requires hands-on training.

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In an extension of this Skills Training module, the MED1stMR project has introduced a second system that zeroes in on the tangible interactions crucial to first responder training. While the primary system focuses on initial triage, the second aims for an elevated level of fidelity in first response patient treatment. To achieve this, it employs a Varjo XR-3 headset with passthrough video capabilities, and chroma-keying with a training manikin. This allows trainees to use real medical tools like stethoscopes, bag valve masks, oxygen masks, and tourniquets in a virtual yet tangible training environment. The tools are stored in a medical backpack for quick and easy access, further mimicking real-world conditions. According to formative evaluations published in the CHI 2023 conference, this approach succeeds in providing an immersive experience without compromising the fidelity essential for effective skills training.

To summarize, the success of MR training in preparing medical first responders rely on choosing the right kind of MR technology tailored to the specific training needs. For skills training modules, a high-fidelity system that combines the dynamic features of virtual environments with real-world, tangible interactions is most effective. Conversely, for training areas focused primarily on decision-making and learning processes, the need for such high-fidelity, tangible interactions may be less pressing, making a broader range of MR technologies suitable. By strategically aligning the MR technology with the training objectives, we can ensure that medical first responders are fully equipped with both the theoretical knowledge and practical skills they need to excel in their roles.

4.4.6 Smart scenario control

Smart scenario control is an advanced feature integrated into the training framework and curriculum, designed to enhance the realism and adaptability of training sessions. Utilizing cutting-edge artificial intelligence (AI) technology, this control mechanism dynamically adjusts training scenarios based on real-time bio-feedback from trainees. By monitoring physiological signals, the system can gauge the stress levels of participants.

For instance, if a trainee exhibits low stress, the system might increase the complexity of the scenario to present a more challenging environment. The current scenarios include stress cues developed based on audio only (e.g. dog barking as a moving sound source) and audio-visual information (a lost child wondering the incident site).

This ensures that trainees are consistently stimulated without being overwhelmed. Furthermore, the integration of wearable technology provides a continuous stream of data, allowing trainers to gain insights into trainees' physiological responses during simulations. The ultimate goal of the smart scenario control feature is to create a tailored training experience that optimally prepares medical first responders for high-pressure, real-world situations.

4.5 Feedback and guidance

Having the capability to record MCI scenario training conducted through an MR-based training enhance trainers' capacity to provide more comprehensive training feedback and evaluations. The availability of a virtual representation of the training environment empowers the trainer to observe

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the performance of MFRs from various camera angles. This addresses the limitations for effectively monitoring the performance of several MFRs simultaneously during real-world, live MCI scenario training. The challenge in the MED1stMR training system turned out to be seeing the difference between who is who among the trainees. In the current MED1stMR training system, all trainees are portrayed in a too similar way even though the technology is available to portray the person's height and shape. In this way, it is difficult for the trainees to distinguish between their team members and also for the trainers to distinguish who is doing what in the scenario.

As the scenario training is conducted in a virtual environment, trainers have the option to pause the scenario in question. This function also extends to having the option to jump directly to a specific (automatically alternatively manually defined), time frame of the scenario, thus allowing MFRs to essentially "rewind the time" to facilitate repeating specific tasks or segments. This feature of the MR based training framework serves as a direct response to the issues raised by MFR trainers regarding the inability to effectively pause large-scale MCI scenario training exercises to provide real-time feedback.

4.6 Evaluation metrics and parameters

Currently, there is no designated or unique way to measure effectiveness of MR training simulation for MCI training. Effectiveness could be assessed by one or a combination of the following outcome parameters:

- *Triage accuracy*: the accuracy of the victim's triage performed by participants
- *Time to triage/time to complete*: the (average) time to complete said triage or decontamination
- *Intervention correctness*: the appropriateness of the medical intervention, focusing on the individual decision-making rather than the ability to perform the task
- *Knowledge assessment*: the cognitive learning achieved.

Within these parameters, MR simulation was shown to be effective.

Another metric that could be used to assess simulation training qualities is the Kirkpatrick model, a globally recognized method of evaluating the results of training and learning programs using four different levels, as shown in Table 3. Level I measure how participants feel about the training programme, level II assesses the degree of learning acquired objectively. Level III with participants' self-efficacy measures the effectiveness of the behaviours learned during the training by the transfer to the job. Finally, Level IV focuses on measuring the impact of training on organizational results. This involves evaluating the tangible outcomes and benefits that the training program brings to the organization. For the respective levels, there are evaluations with increasing complexity.

Table 3: Kirckpatrick levels of effective simulation training

Levels	Definition
Level I Reaction	A measure of how participants feel about the training program

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Level II Learning	An objective, quantifiable measure of how well trainees have acquired knowledge, improved skills, or changed attitudes due to training
Level III Behaviour	A measure of how well behaviours learned in training are performed on the job (i.e., transfer of training)
Level IV Outcome	A measure of how well training relates to results, such as improved patient outcomes, reduced costs, enhanced quality

4.7 Improvements of MFR performance and processes in MCIs

The MR training system for MCI training improve the ability to act appropriately during MCIs and to handle tasks and internal stress better. Through MR simulation training, trainees can learn how to handle excessive demand (personal and structural) occurring during any MCI. MR training increase training opportunities in MCI which are currently lacking, by allowing more MFRs to train more often. Through this increased quantity of training, MFR trainees are able to improve their understanding of the mechanisms underlying MCI procedures. Specifically, the emphasis should be on the differences (and similarities) between their daily assignments and MCIs. By that, they become better prepared for MCIs and the rescue organisation can handle the situation more effectively. A MR system also allows a greater level of repeatability, as situations can be recreated and re-trained according to the identified needs in a training session.

Second, the procedures and processes during MCIs could be improved. Providing various novel ways to quantify and objectify results of an MCI exercise enables organisations to properly evaluate whether procedures work, where weaknesses lie, and which aspects in MCI handling (and teaching thereof) should be changed. Additionally, training MCIs with MR also facilitates end user organisations to try out new procedures and concepts and assess their potential in a safe environment.

5 MR training assessment

A critical aspect of implementing MR training for MFRs involves the comprehensive assessment of their abilities and training outcomes. This chapter explores the key considerations for conducting effective MR assessments tailored to the unique demands of MFR training.

5.1 Validity and Reliability

Assessing the validity and reliability of MR-based assessments is paramount to ensure accurate and consistent measurement of MFRs' capabilities. This entails evaluating the extent to which the assessment aligns with its intended purpose and the precision of the obtained results.

- Validity

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- Ensuring that the assessment accurately measures the targeted skills and competencies relevant to MFR roles.
- Conducting thorough validation studies to establish the assessment's effectiveness in capturing essential proficiencies.

- Reliability
    - Assessing the consistency and dependability of assessment outcomes over multiple trials or instances.
    - Employing statistical techniques to validate the reliability of the assessment tool.

5.2 Feasibility and Usability

The feasibility and usability of MR assessments are crucial factors influencing their adoption and effectiveness in MFR training contexts. This encompasses factors such as accessibility, affordability, and ease of use.

- Accessibility
    - Ensuring that the MR assessment tools and technologies are readily available to MFRs, regardless of location or resources.
    - Implementing user-friendly interfaces and platforms that facilitate easy access and navigation.
- Affordability
    - Considering the economic feasibility of deploying MR assessment solutions, including hardware, software, and associated training costs.
    - Exploring cost-effective alternatives without compromising assessment quality.
- User Satisfaction
    - Gauging the level of satisfaction and comfort experienced by MFRs and instructors when utilizing the assessment tools.
    - Gathering feedback and making necessary adjustments to enhance user experience.

5.3 Ethical and Legal Considerations

Addressing ethical and legal aspects is imperative to safeguard the rights, privacy, and security of MFRs participating in MR assessments.

- Privacy and Data Security
    - Implementing robust measures to protect sensitive information collected during assessments.
    - Adhering to established data protection regulations and guidelines.
- Ownership of Assessment Data

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- Clarifying ownership rights regarding assessment data, including storage, analysis, and potential sharing with relevant stakeholders.

- Debriefing and Feedback
  - Establishing protocols for debriefing MFRs after assessments to provide constructive feedback and address any concerns or questions.
  - Ensuring transparency in the assessment process and its implications.

5.4 Measuring Effectiveness, Efficiency, and Impact

The assessment process should comprehensively evaluate the impact of MR training on both individual trainees and the broader organizational context.

- Effectiveness
  - Assessing the extent to which MFRs have acquired and applied the necessary skills and knowledge through MR training.
  - Using performance metrics and feedback mechanisms to quantify learning outcomes.
- Efficiency
  - Evaluating the efficiency of the MR training approach in terms of resource utilization, time effectiveness, and overall training process optimization.
- Organizational Impact
  - Analyzing the broader organizational benefits derived from implementing MR-based training for MFRs, including enhanced response times, improved patient care, and cost-effectiveness.

A well-structured MR assessment framework for MFRs encompasses validity, reliability, feasibility, usability, ethical considerations, and a focus on measuring effectiveness, efficiency, and impact. By prioritizing these factors, organizations can ensure that MR training initiatives for MFRs yield optimal results, ultimately leading to enhanced emergency response capabilities and improved patient outcomes.

6 Impact of MR based training framework

The adoption of MR technology in medical first responder training bears immense potential to enhance overall preparedness and efficiency. EU policy makers are at the forefront of recognizing the impact of MR training in this critical sector given its implications for disaster response, healthcare and education policies within the EU.

6.1 Harmonizing training across the Member States

In order to operate seamlessly and ensure effective and timely response to disasters, a harmonized approach to healthcare training and standards is encouraged. MED1stMR's training offers a way to

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bridge gaps in training methodologies across member states as a tool to unify medical first responder training practices, promoting consistency and quality. The EU Module Exercises (EU MODEX), training Emergency Medical Teams and other Response Capacities across Europe, would be an excellent testing ground within the EU Civil Protection Mechanism (CPM). As the CPM facilitates cooperation among EU Member States and other participating countries in disaster response, it highlights the importance of strengthening preparedness through training programmes and exercises with a particular focus on scenario-building, asset mapping and the development of plans for the deployment of response capacities to increase preparedness.

6.2 Strengthening cross-border collaboration and addressing workforce mobility

The scale, transportability and relative ease of setup of the MED1stMR training solution facilitates cross-border collaboration among medical first responders.

Policies should encourage the adoption of MR training as a mean to enhance inter-country cooperation during crises, as do International Agreements and Frameworks (e.g. the Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goals), regional agreements and harmonization, International Information Sharing Agreements, Interoperable Systems as well as legal and ethical frameworks.

Furthermore, as part of the EU workforce, healthcare professionals regularly move across borders, making MR training instrumental in the strive to standardize skill sets and common qualifications, facilitating mobility for medical first responders to work in different member states. Since different healthcare models exist among Member States, from strictly hierarchical to fully decentralised, easily adaptable scenarios to different structures are crucial. The MED1stMR training solution offers possibilities for harmonization concerning the consensus about the methods corresponding to the need for realistic training of first responders and structured post-training evaluation.

6.3 Reaching EU targets in reducing mortality

The European Union is currently adopting a ‘Road Safety Package’, aiming to move as close as possible to zero fatalities in road transport by 2050 (‘EU’s Vision Zero’). In 2022, an estimated 20,600 people were killed in road crashes in the EU (European Commission, 2023). The first minutes after a road traffic incident are often the pivotal moment to save lives. While the emergency medical services need to be activated and to arrive on the scene, having a trained bystander able to provide First Aid makes a key difference for the casualties. The European Resuscitation Council Guidelines 2021 on First Aid together with the evidence collected by the International Liaison Committee on Resuscitation (ILCOR) strongly confirm that First Aid reduces morbidity and mortality in a variety of clinical scenarios, from respiratory illnesses to trauma and from bleeding to cardiac arrest (Zideman, et al., 2021).

Furthermore, sudden cardiac arrest remains one of the leading causes of death in Europe, with about 55 to 113 cases per 100,000 inhabitants a year, or 350,000 to 700,000 individuals affected depending

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on how it is defined (Zideman et al, 2015). Around 25% to 50% of casualties present a rhythm that would benefit from defibrillation. For every minute that someone's in cardiac arrest without receiving help, their chance of survival decreases by 10%. In this regard, the MED1stMR contributes to building safer and healthier communities.

6.4 Data protection and privacy regulations

The MED1stMR training generates sensitive data on trainees' performance (including biodata generated by ECG sensors and EDA) which impacts regulations to ensure data protection and privacy compliance. These policies safeguard individuals' data rights and promote trust in MR training systems (including Consent and Transparency, Data Minimization, Purpose Limitation such as performance assessment and training improvement, Data Security, Data Transfer and international data transfer, Data Retention, Data Subject Rights, DPIAs, DPO and Privacy by Design and Default). A strong EU personal data protection (e.g. GDPR) could provide an advantage to Europeans in terms of trust in data safety and make them more willing to use MR solutions.

6.5 Market and research opportunities

The integration of Mixed Reality technology into medical first responder training is prompting significant shifts in EU healthcare policies, including support for innovation and collaboration with industry stakeholders. The European market for Virtual Reality in general is expected to grow exponentially between 2018 and 2026. With an average annual growth rate of an impressive 35%, the market is projected to reach a value of around €43 billion in 2026. This is more than ten times the market size of 2018 (CBI, 2021, September 08).

Moreover, collaborations with already developed EU solutions (e.g. *SimforHealth*, *THRIVE* or *Vireed Med*) are an interesting option to develop industrial projects.

As the result of a multi-disciplinary collaboration among novel technology, human experience, hardware solutions, medical and psychological research, the MED1stMR solution is opening doors to further research in the field of virtual and mixed reality, which is currently a hot topic in the international scientific community.

6.6 Impact regarding Disaster Resilient Society

MED1stMR and its mixed reality training will improve the overall capabilities of medical first responders, which will result in better, safer, sounder rescue operations and a decrease in unwanted incidents. It is also expected to decrease the number of casualties and improve the pre-hospital life support during large-scale incidents in Europe. MED1stMR's training provides a dynamic, immersive environment where emergency responders can simulate disaster scenarios realistically. They can practice critical skills, decision-making, and teamwork under various disaster conditions, improving their readiness. This leads to a more resilient response when actual disasters occur. Research has consistently shown that well-trained first responders are crucial for effective disaster management (Cimellaro et al., 2019). Furthermore, disaster resilience extends beyond first responders to

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communities as a whole. The MED1stMR training can also have implications at community-level disaster preparedness and education. By incorporating community members into MR training programs, it may empower individuals to better understand disaster risks and adopt mitigation measures (Fuchs et al., 2021).

From an environmental point of view, the (partial) replacement of real-world training by mixed-reality training has a positive impact. Building training sights and settings, transporting materials, using real consumption items and travelling of medical personnel, actors and helpers to training centres and sites causes a certain level of CO2 emission. Virtual training settings minimise this factor thanks to resource reusability.

From an economical point of view, first responder organisations will benefit from virtual training solution in the long-term. Thus, it eliminates consumables, actors, travel and accommodation costs, and allows multi-site training to make optimal use of the available budget.

From an educational point of view, the MED1stMR technology can be used in formal, non-formal and informal settings to achieve specific training objectives. Moreover, the MED1stMR technology supports the development of computational thinking skills. Through virtual scenarios, the challenges posed by traditional learning approaches (e.g. the visualisation of problems) can be addressed. Participating virtually in learning processes overcomes the limitation of collaborative scientific experimentation. It can also augment trainers' lesson materials by providing improved access to materials.

An inclusive aspect of the MR technology relies in its affordability to people with disabilities or weak health condition. The virtual environment is also by definition without risks to physical health.

Improved decision-making and disaster response coordination:

Disasters often require swift and informed decision-making. By replicating high-pressure situations in the scenarios, the training allows responders to develop the capacity for effective decision-making in real-time ultimately leading to better-coordinated responses.

Effective disaster response often relies on seamless coordination among first responders and various agencies (Comfort et al., 2019). MCIs require the presence of many kinds of first responders and the training to facilitate realistic interagency exercises, fostering cooperation and improving communication protocols. This strengthens the overall disaster response ecosystem. It enables responders to practice communication and interagency collaboration in complex disaster scenarios, leading to better-coordinated responses (Türk et al., 2018).

Adaptive training modules:

Disaster risks are evolving due to climate change and technological advancements. Due to the editability of the scenarios, the MED1stMR training can be updated easily to reflect these changing conditions. This adaptability ensures that responders are well-prepared for emerging challenges, contributing to long-term resilience.

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Optimized resource allocation:

Efficient resource allocation is critical during disasters (Cui et al., 2020). MR training can simulate resource management scenarios, allowing first responders to make informed decisions regarding resource allocation and utilization. The MED1stMR provides insights into how MR training can optimize resource allocation, leading to more effective disaster responses.

Data-driven decision-making:

Data-driven decision-making is critical in disaster management (Jiang et al., 2021). The collected data on trainee performance can be leveraged for evidence-based decision-making in disaster scenarios, aligning with modern disaster resilience strategies.

7 Relevant perspectives

7.1 Gender

Gender issues in the MR training approach itself may arise from using only a male manikin as some treatments are different based on gender. On a similar note, performing treatments in the chest area of young women can be uncomfortable for young males as the standard for training is usually a male body were reported as potential gender issues. It can also be problematic when MFRs are confronted with patients from other cultural backgrounds, when they have to deal with people who belong to religious groups that forbid men to touch women or children, and vice versa. However, there are no gender-related differences in the use of MR training equipment, devices and the operation of the system for trainers and trainees.

7.2 Legal

Both MR providers and end users (MFR organisations) must think carefully about the internal legal agreement to ensure that they:

- Protect existing rights (copyright of software, pictures of material, publishing data, dissemination).
- Allocate future rights of any new creation (duty of confidentiality, test options)
- Determine legal settlement in the event of costumer failure or abuse of MR system.
- Determine legal settlement of MR provider responsibility in the event of (technological) failure of MR system.
- Determine legal settlement in the event of personal injury (motion control, epileptic seizures) and product liability (copycat-violence, trauma).

7.3 Ethical

Using XR for FR training offers immersive experiences, replicating real-world cognitive and behavioural responses. While this enhances training realism, it can also risk psychological well-being. High-stress scenarios, without proper management, can cause anxiety or trauma. Ethical design is crucial to ensure

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psychological safety and manage potential dissociation from reality due to extended XR use. Additionally, repeated exposure to certain virtual actions might influence real-world behaviour. For instance, continuous exposure to virtual violence could desensitize first responders or foster aggression in actual situations.

Autonomous decision-making and learning capabilities of AI supported systems can include hidden biases that manifest in data collection, model development and interpretation of results, potentially leading to unfair or discriminatory outcomes. While there is no concrete set of rules and framework in place to mitigate against such risks, organizations using AI-supported MR training solutions should implement regular evaluation processes to analyse ML algorithms and proposed outcomes for potential biases (e.g. Measurement bias, Non-response bias or Algorithmic bias).

7.4 Safety

End-user organisations and policy-makers needs to consider the normal safety precautions (as in real-life MFR training) and apply these precautions to MR training. Previously established rules of conduct for real-life training, such as interaction with fellow trainees and "no-play" provisions can be applied to MR. Nevertheless, there are some MR-specific points that policy makers should consider when it comes to physical and psychological/social safety of trainees.

7.4.1 Physical safety in training

Regarding safety concerns, there is no significant risk for physical danger, however physical protections for elbows and knees, similarly to what is used in current training, could be used. In addition, organisations can take out insurance for possible accidents during MR training.

- As the physical aspect is less present, MR provides a safe environment to train high-risk situations with minimal risk of physical harm (injuries) to trainees.
- Motion sickness can lead to dropout of trainees in training and negative experience with MR. Specific protocols should be developed, possibly in collaboration with the MR provider (technical requirements) to reduce motion sickness.
- When dressing or undressing body sensors (e.g. PLUX devices) with direct contact to the skin, an area should be set-up to provide privacy for trainees.
- When using the live monitoring within the Real-Time Training Progress Assessment Tool, during a MR training session, the possibility exists that trainers or operators might notice abnormalities in heart rate (irregular or too high) or chronic stress (low HRV baseline levels) of trainees. End-user organizations in cooperation with training coordinators should develop a protocol that addresses incidental medical findings and how these will be handled a) if noticed during a training session and b) if noticed after a training session, indicating possible medical risk to the trainee.

7.4.2 Psychological and Social Safety in Training

While concerns about physical danger are limited, MFRs are at the risks of **psychological danger**. In fact, participants consider exposure to potential psychological triggers a risk factor that may affect

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MFRs outside the training environment. As a solution, it necessary to have psychological help available during and after training. In this way, the psychological integrity of the trainees can always be safeguarded.

7.5 Privacy

In the EU the General Data Protection Regulation (GDPR) governs the privacy and security of personal data, that includes provisions that could impact how data is collected and used in AI-supported MR training solutions. For instance, Article 22 of the GDPR relates to automated individual decision-making, including profiling. It provides individuals with the right not to be subject to decisions based solely on automated processing, including profiling, which produces legal effects or similarly significantly affects them.

MR systems offer great possibility to store valuable training information as MR features that enable trainers to monitor how trainees move around in the virtual environment, store training data and monitor progress and performance over time (for in action monitoring and after-action review). These possibilities ask for proper policy development, particularly on data storage of MR training output.

In particular, the following points need to be considered by organizations and policymakers:

- Anonymity of data
- Short vs. long-term storage (i.e., how long is the data stored for?)
- Accessibility to stored data (i.e., if data is stored, who has access and how can the data be accessed?)
- Visibility of individual data when team viewing in the de-briefing (e.g.: Stress levels are visualized during the training – if individually influenced stress-level increases are visualised this might be a private issue for trainees and might only be discussed with a trainer and not with all peers – turning on and off might be an easy solution for that)
- MR system use: disconnect from public channels (i.e., use of a free radio channel, operating in a local network isolated from the internet)

7.6 Logistical perspective

Implementing a successful MR training program requires meticulous attention to various logistical aspects. This section provides a detailed overview of key components and considerations essential for the seamless set-up and execution of MR training sessions.

7.6.1 Location

Selecting an appropriate location is essential for the effective deployment of a MR training system. The chosen space must meet specific criteria to ensure an optimal training environment.

- **Space requirement**: Adequate room dimensions are essential to accommodate the MR equipment and allow trainees ample freedom of movement for an immersive experience. Clearing obstructions and ensuring unobstructed play areas are essential considerations.

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- **Power supply**: An ample and reliable power supply is paramount to sustain all components. This includes powering MR headsets, peripheral devices, and any supporting hardware. Prioritizing access to power outlets and potentially utilizing surge protectors can mitigate any power-related disruptions during training.
- **Wi-Fi connectivity**: Robust and stable Wi-Fi connectivity is imperative for seamless operation. It enables uninterrupted communication between MR devices and ensures the fluid functioning of interactive elements within the training scenarios. Verifying signal strength and exploring potential network redundancies can safeguard against connectivity issues.

7.6.2 Components to Ship

Efficient transportation and careful handling of MR equipment are fundamental for the success of any training session.

- **MR headsets**: Ensuring that each trainee has access to a functional and properly calibrated MR headset tailored to the specific training program is paramount. Rigorous pre-session testing of headsets can preemptively address any hardware concerns.
- **Peripheral devices**: This encompasses controllers, sensors, and any additional equipment required to augment specific training scenarios. Proper organization and labeling of peripherals streamline the set-up process and facilitate quick troubleshooting.
- **Supporting hardware**: In addition to MR-specific components, consider any accompanying hardware such as laptops or computers that may be necessary for system operation and data management. Verifying the compatibility of supporting hardware with the MR system is essential.

7.6.3 Group Setting

Establishing an appropriate group dynamic is critical for collaborative learning in MR training.

- **Arrangement**: Thoughtful planning of the physical layout of the training area encourages interaction and communication among trainees. Configuring seating or standing arrangements to facilitate easy visual and auditory access to trainers and peers is beneficial.
- **Group size**: Determining the optimal number of participants per session is a multifaceted decision. Consider factors such as the available equipment, complexity of training scenarios, and the need for personalized attention. Striking the right balance ensures an effective learning experience for all participants.

7.6.4 Trainees

Understanding the unique needs and capabilities of trainees is essential for tailoring the MR training experience.

- **Experience level**: Conducting an initial assessment of trainees' familiarity with MR technology informs the level of support and guidance required. Tailoring the training pace and complexity to accommodate both beginners and more experienced users ensures an inclusive learning environment.

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- **Personalization**: Customizing training scenarios based on trainees' roles, responsibilities, specific learning objectives and stress level amplifies the relevance and applicability of the training content. This approach empowers trainees to directly apply newfound skills in their respective roles.

7.6.5 Trainers

Empowering trainers with the requisite knowledge and resources is pivotal for a successful MR training program.

- **Train the trainer:** Providing comprehensive training for instructors on the operation of the MR system is essential. This includes troubleshooting common issues, familiarizing them with potential challenges, and imparting strategies for facilitating effective training sessions.
- **Trainer guide**: Developing a comprehensive guide that outlines session objectives, step-by-step instructions, potential challenges, and suggested interventions empowers trainers to lead with confidence. This guide serves as a valuable resource for trainers to reference during sessions, ensuring consistent and high-quality delivery.

A well-organized logistical framework is instrumental in the effective execution of a MR training program. By addressing factors such as location suitability, equipment transportation, group dynamics, and trainer preparedness, organizations can ensure that MR training sessions are conducted smoothly. This, in turn, maximizes the benefits for trainees and ultimately enhances the overall learning experience.

8 Summary

In summary, the lack of realism and challenges in post-training evaluation creates a gap between how MFRs are trained and the complex nature of real-world disaster incidents. The MR based training framework was developed by MED1stMR as a direct response to these limitations. The framework enables a dynamic training environment, allowing trainers to design realistic scenario exercises. However, in its current state, the MR system has limitations, such as the size of the training area, which affects its ability to realistically represent certain situations.

To enhance realism, the system utilizes patient simulation manikins and customizable avatars for injured individuals capable of rendering injuries and reactions more authentically than human actors. Future developments include the integration of artificial intelligence to guide avatars, streamlining training and making it more realistic.

To address the challenges in post-training evaluation, the MED1stMR project provides the ability to record training sessions and use virtual representations of the environment to assess the performance of MFRs from various camera angles. This facilitates trainers' assessment of MFRs' actions. The system can also pause and rewind scenario exercises for specific moments to improve feedback and post-training evaluation.

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Ultimately, by integrating realism and improved evaluation into the training system, the goal is to enhance the readiness and capability of MFRs to handle real-life disaster situations more effectively.

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