European Commission, Horizon 2020

D7.6 SHOTPROS Final Guidelines for VR Training

SHOTPROS

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Deliverable Lead	AIT
Related work package	WP7
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Versions

Vers.	Date	Author	Description
V0.1	8/06/22	Olivia Zechner (AIT)	First draft of structure and content
V0.2	21/06/22	Olivia Zechner (AIT) Helmut Schrom-Feiertag (AIT)	Adjustment and adaptation of the structure and content to D7.5
V0.3	4/07/22	Olivia Zechner (AIT)	Detailing the structure and including additional content
V0.4	20/07/22	Olivia Zechner (AIT) Helmut Schrom-Feiertag (AIT)	Coordinating and including technical descriptions for the SHOTPROS system
V0.5	23/08/22	Olivia Zechner (AIT) Jakob Uhl (AIT) Helmut Schrom-Feiertag (AIT) Emma Jaspaert (VUA)	Alignment with D7.5, further detailing of technical and LEA specific requirements, results from field trials and stressor materialisation and ethics.
V0.6	31/08/22	Olivia Zechner (AIT) Jakob Uhl (AIT) Helmut Schrom-Feiertag (AIT)	Version for LEA partner review
V0.7	12/09/22	Olivia Zechner (AIT) Jakob Uhl (AIT) Helmut Schrom-Feiertag (AIT)	User experience studies, future developments and appendix
V0.8	16/09/22	Olivia Zechner (AIT) Jakob Uhl (AIT) Helmut Schrom-Feiertag (AIT)	Revision based on the partner feedback
V0.9	26/09/22	Olivia Zechner (AIT) Jakob Uhl (AIT) Helmut Schrom-Feiertag (AIT)	Revised complete version
V1.0	30/09/22	Birgit Harthum (USE) Valerie Schlagenhaufen (USE) Gerhard Helletzgruber (USE)	Final check, formatting and submission

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List of Acronyms and Abbreviations

Acronym/ Abbreviation	
AAR	After-Action Review
DMA-SR	Decision Making and Acting under Stress and in High-Risk Situations
HF	Human Factors
HR	Heart Rate
HRV	Heart Rate Variability
IAM	In-Action Monitoring
KPI	Key Performance Indicator
LEA	Law Enforcement Agency
NPC	Non-Player Character (computer-controlled character)
RAT	Risk Assessment Tool
RR	Respiration Rate
RTTPAT	Real-Time Training Progress Assessment Tool
RVTD	Real-Time Trainer Dashboard
VE	Virtual Environment
VR	Virtual Reality

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1 Executive Summary

This deliverable provides support and technical guidelines for law enforcement agencies (LEAs) interested in adopting virtual reality (VR) training for Decision Making and Acting under Stress and in High-Risk Situations (DMA-SR). It covers an overview of hardware and software requirement considerations as well as considerations regarding training facilities, resources, training set-up and preparation. The description of the actual SHOTPROS VR solution, the technological result of the project, is included in all considerations to show how the DMA-SR aspects are implemented in the tangible results of SHOTPROS, the training tool.

D7.6 delivers an overview about training areas and the related usefulness of VR by describing considerations for the evaluation of VR systems in terms of technical requirements and explanations as well as a compilation of the LEA requirements for police training. SHOTPROS introduced and evaluated significant technical innovations for DMA-SR VR police training including a Live Editor to alter the training scenario on the fly, a tangible tactical belt to train as naturally as possible, the Virtual Character Control supporting de-escalation training, the Real-Time Stress Dashboard (Monitoring & Manipulation – see D4.5) to personalise training to the trainees needs and Performance Management (Stress & Key Performance Indicators) in the after-action review (AAR) to strengthen learning. After the description of hardware and software guidelines for DMA-SR training in the VR, the document also deals with challenges of VR (data protection, security, privacy for data recorded during training and ethical aspects) that need to be considered and then summarises the results from the user studies and field trials with the SHOTPROS VR training system and highlights the relevant aspects that need to be met for a positive user experience and high acceptance by police trainers and trainees. Finally, an outlook on promising future developments and improvements based on the status quo is provided.

In combination with D7.5, which covers the training curriculum and didactical guidelines, this deliverable at hand will provide technical insights and guidelines necessary to evaluate or develop a VR training solution for DMA-SR training in European LEA organisations from a user point of view.

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2 Added Value

2.1 Relation to the SHOTPROS Work packages (WPs)

Deliverable D7.6 is a result of WP7 which covers the evaluation and validation of the VR training solution in the field trials (FTs) with end users to generate the needed results (see Figure 1). During the FTs, the ongoing developments in WP5 based on the feedback from the human factor (HF) studies (WP6), improved the technology readiness level in individual categories, which also led to a better user experience and more positive feedback in the course of the field trials and to an exploitable SHOTPROS VR training solution.

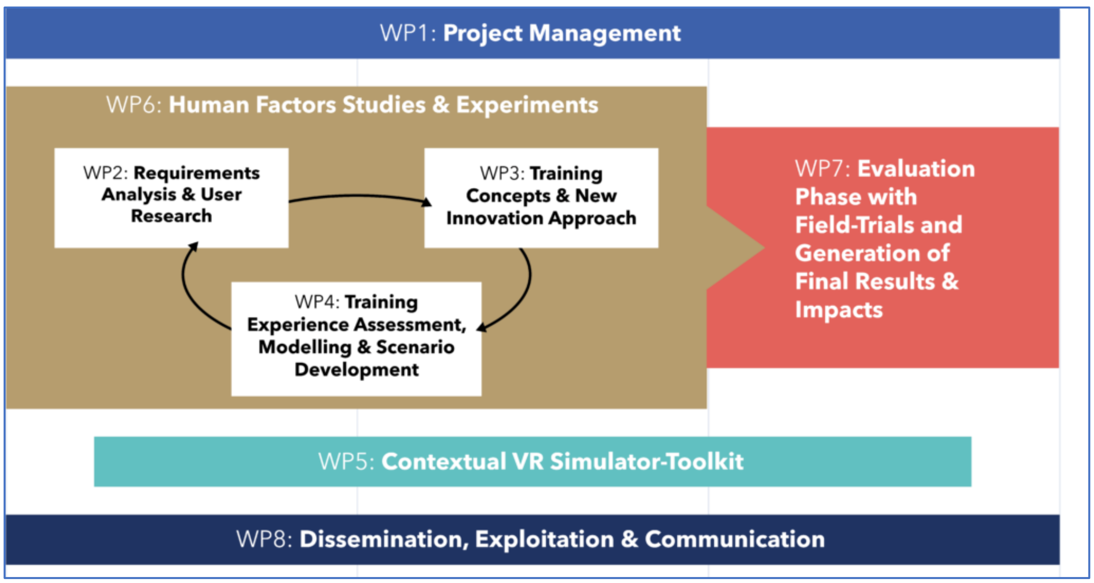

Figure 1: SHOTPROS work packages. WP4, WP2 and WP3 build the basis to set up the VR solution (WP5) which is evaluated in the field trials in WP7.

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2.2 D7.6 is informed by the following deliverables

Several other SHOTPROS deliverables have influenced the results of this deliverable:

No.	Title	Information on which to build
D2.2	LEAs Point of View: Requirement Report, Stakeholder Map and Expectation Summary for DMA-SR Model and Training Framework and Curriculum	First overview of identified user requirements and recommendations for the DMA-SR training and further developments for the VR training system within SHOTPROS. Factors influencing human decision making and acting in stressful situations and relevant stress cues identified in the requirement phase and later translated into technical requirements and guidelines.
D2.3	Guidelines and Input for the future Training Scenarios	The options for (real-time) adaptions to scenarios during a training have been highlighted as indispensable for successful trainings and included in the guidelines.
D2.4	EU Citizens Study Report on Perceived Behaviour of Police Officers and Impacts for the DMA Model & Training Framework	The surveys of D2.4 built the basis of the questionnaires used in our end user feedback weeks and field trials, which are reported on in detail in this deliverable.
D3.1	Overview of Current Training and Best Practices of Training Curricula in European LEAs and Impacts on the DMA-SR Modell and Training	Current practice of training methods helping to identify areas for which VR can add value to current practices and relevant technological requirements for VR training system.
D3.2	Conceptual Model of DMA-SR Behaviour and a Research Agenda to validate the Conceptual Model	The foundation of the DMA training is laid by the scientific model and therefore influences the requirements towards an ideal VR solution for police VR training. Definition of stress, triggers, and stimuli to evoke stress reactions in trainees. The translation of this stimuli into audio-visual stress cues provides suggestions on the technical requirements and are reflected in the guidelines.
D3.3	European Framework for Training and Assessment	Provides an extensive evidence-based set of recommendations for implementing VR DMA-SR training in current police curricula. Especially because of the

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	of DMA-SR Behaviour of Professionals	physiological measurements, the ethical, safety and privacy issues included in this document play an important role.
D4.1	Cue Repository for Personalization and Customization of VR Training Scenarios	The identified cue repository weighted by the LEAs defines the basis for the stressors that are used to alter the scenario. The technical implementation constitutes challenges for the VR system.
D4.3	Concept for Physiological Measurement Suite for Stress Assessment	The concept for Physiological Measurement Suite for Stress Assessment defines what to measure and how to assess the stress level.
D4.4	Training Experience Framework and Structural Equation Model	Results of studies conducted in D4.4 revealed which questions, of the variety of questionnaires tested, are the most useful when it comes to system improvements and overall guidelines for VR DMA training.
D4.5	Real-Time Training Progress Assessment Tool	The resulting In-Action Monitoring tool takes into account multiple technical and usability requirements and included in the guidelines.
D4.6	Create Technical Requirements for VR Training Scenarios	Together with D2.2, the requirements backlog in D4.6 build the complete overview of technical needs towards a VR police training solution and scenarios within SHOTPROS.
D4.7	Risk Assessment Toolkit to identify High-Risk Situations	To use the full range of VR technology for training, scenarios need to reflect risk situations for the trainees, which was developed in D4.7
D5.1	VR System Design Document for development of SHOTPROS VR Environment for conducting the Human Factor Studies and the Field Trials	The defined requirements & prototypes (from WP4) were the fundament for the design and implementation of the VR system(s). The components and all innovations and beyond state of the art are described and build a basis for the guidelines in this document.
D5.2	Agile Development of VR Test Scenarios & Environment and Preparation & Provisioning of Infrastructure for conducting the Human Factor Studies	With this demonstrator the human factor studies were executed and iteratively further developed based on the feedback. Also, extensive feedback on technical requirements.

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D5.4	VR Results Dashboard for Reviewing and Measuring Training Sessions Performance and Output for Evaluation and Field Trials	Final dashboard for the After-Action Review from which various technical as well as training aspects have been determined and taken into account and are included here.
D6.1	Human Factors Study Plan	Plan of study execution in the project. These studies also assessed how well the requirements defined in D2.2 were met, which included the technical requirements.
D6.2	Human Factors Measurement Toolkit	The collected data from all the HF studies served as basis for the evaluation and recommendation for the VR guidelines.
D7.1	Field Trial Methodology and Planning	In D7.1, the validation of the research and development results was defined in order to obtain the necessary feedback on acceptance, quality of use and efficiency. These procedures were used to collect important information for the VR guidelines.
D7.2	Field Trial Combined Analysis Report	It describes preliminary research findings of the field trials and forms a basis for this document on usability, acceptance of VR training and the stressors used in scenarios.
D7.4	SHOTPROS Final Evidence-based HF model for DMA-SR	The scientific model on which the DMA-SR training solution is based, delivers insights on what is important to execute DMA-SR training within the VR.
D7.5	SHOTPROS Final Training Curriculum for DMA-SR	This deliverable defines an evidence-based set on recommendations for implementing VR DMS-SR training in current police curricula. It has a didactical focus which is also in interplay with the technical requirements and guidelines in this deliverable.

Table 1: The work of the document builds on results from the previous deliverables.

2.3 D7.6 consequently feeds into the following deliverables

No.	Title	Information on which to build
D7.5	SHOTPROS Final Training Curriculum for DMA-SR	The technology and developments fundamentally determine the possibilities with VR. D7.6 delivers guidelines about technical aspects and therefore influences D7.5 the final training curriculum. Only what

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		is made possible by the technology can also be implemented as a recommendation in a training. D7.5 in turn describes how to use them correctly in training.
D7.7	SHOTPROS Final Evaluated VR training scenarios	The guidelines developed in D7.6 are necessary to set up DMA-SR considering VR scenarios for LEAs.
D8.5	Strategies & Toolkit for Policy-Makers	Guidelines towards a VR solution also include requirements regarding the implementation, the first introduction within an organisation and therefore influences D8.5, the policy maker toolkit
D8.6	Exploitation Plan, Innovation Management and Business Outlook	The VR guidelines cover needs towards a final product and therefore influences the Exploitation Plan and Business outlook of SHOTPROS.

Table 2: The work of the document builds on results from the previous deliverables.

2.4 Relation to SHOTPROS objectives

Deliverable D7.6 provides the final guidelines for VR training from a technological point of view and therefore mainly contributes to SHOTPROS objective 4 "Guidelines for VR training" (see Figure 2). The D7.6 VR guidelines aim to make the knowledge gained on VR training available for building training systems with VR technologies and for future developments. To this end, it summarises all the knowledge on VR technology in the form of guidelines that can serve as a basis for the technological assessment of a VR training environment (objective 2) and integration of VR training technology into the existing training practices of European LEAs (objective 3). These guidelines, based on the results of the requirements analysis and evaluation with end users, also contribute to the efforts of a harmonised and standardised VR training for police training from which the European police network would greatly benefit and strengthen it (objective 5).

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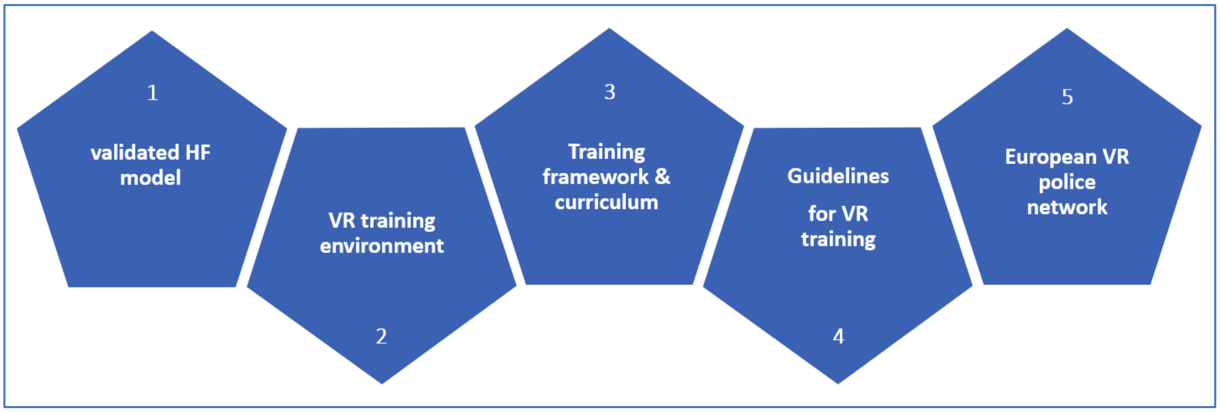

Figure 2: The 5 SHOTPROS objectives

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3 Introduction

After 42 months of continuous development, numerous studies and field trials, this document summarises the findings for a VR system for DMA-SR police training from a technological point of view. This document will provide an overview of VR training system components and its variations, with a focus on LEA specific aspects required for scenario-based training, potential challenges and current technical limitations.

To use VR technology for DMA-SR police training, a VR system is needed that meets the requirements (see D4.6) of LEA organisations. Throughout the SHOTPROS project continuous studies were conducted to constantly evaluate current technology versions and the progress made (agile approach – see D1.1). Together with the end user partners of SHOTPROS, these requirements were assessed, implemented, and evaluated in multiple training sessions (see D6.1 – HF studies and FTs) and resulted in the SHOTPROS VR solution (see D5.1). It was important for the LEA partners to get an understanding of the VR technology and to explore the possibilities in the context of existing training practices but at the same time include the knowledge of DMA-SR training into a new technology. Insights gained about user experience, stress induction, key performance indicators relevant for police training and the impact of multi-sensory experience were considered in the development of the SHOTPROS VR solution and will be exploited into a market-ready product after the end of the project.

As an argument against the introduction of VR technology in police training, it is often mentioned that VR cannot substitute real-life trainings. But the technology should not be seen as digitalisation or virtualisation of existing training, but rather as an additional option that can be used to train situations that are difficult to practice in real-world training. VR is suitable for certain training types and there the advantages of VR should be used to enhance the results in comparison to real-life trainings. For example, effective virtual environments can be developed to train tactical skills and personal safety procedures. To train with firearms (as shooting precision is often not sensitive enough in VR and exact shooting typically needs to be trained with the real-life equipment to enhance muscle memory) or close combat skills (as it is currently not possible to recreate realistic physical contact with a virtual only non-player character (NPC)), VR might not be the best medium for this kind of training. Hence, it is crucial to define training goals and frameworks (see D7.5) before introducing a VR training system to the organisation (see D8.5). Initial acquisition of a VR training system will very likely come with some degree of customisation to cover organisation- or country-

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specific requirements and therefore needs a considerable investment of time and budget. To support LEAs in this process, we provide checklists and worksheets in the appendix. Additionally, D8.5 Policy Maker Toolkit, provides strategies and toolkits for persons who have the authority to introduce the VR training framework (D7.5) and guidelines (D7.6) into law enforcement organisations.

While this deliverable (D7.6) focuses on the technical aspects of VR training and provides insights on VR system evaluation considerations and factors highlighted throughout the project as important for future improvements of VR systems, deliverable D7.5 provides didactical guidelines regarding a VR training curriculum including aspects such as structure of a VR training session, the process including the training session itself, training analysis and feedback sessions. To get a comprehensive understanding of all components important to training in virtual environments (VE) we recommend reading this deliverable D7.6 in combination with D7.5.

For a clear overview on the final SHOTPROS deliverables regarding the SHOTPROS solution, the following overview is available in all introduction chapters of the regarding deliverable. Here it is visible which final deliverables influence the SHOTPROS VR solution and where to find which information:

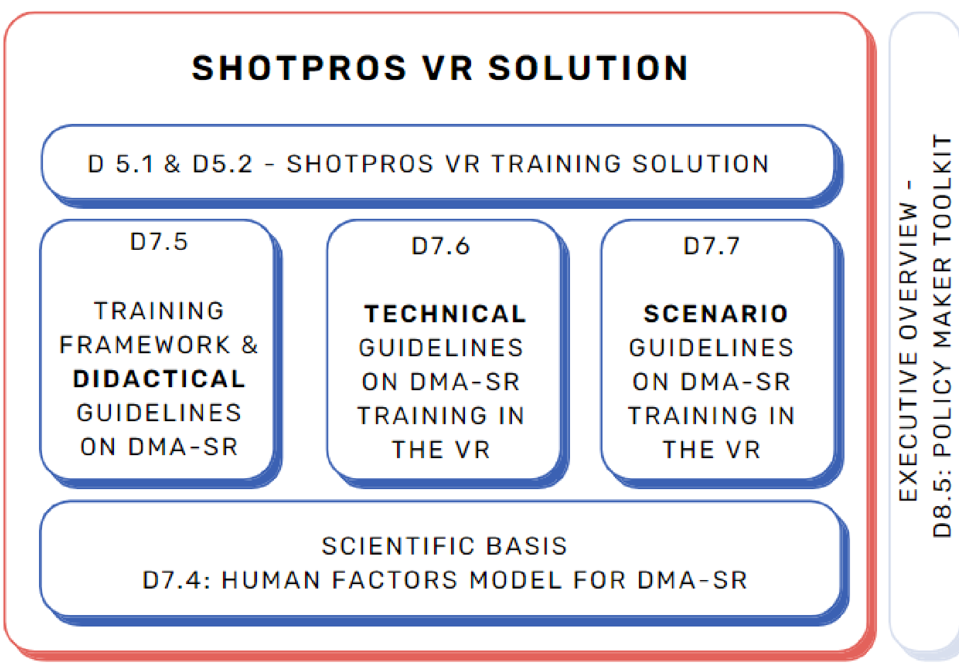

Figure 3: SHOTPROS VR solution – overview on final deliverables

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4 SHOTPROS VR Solution

One of the main results of the SHOTPROS project is the SHOTPROS VR solution – a tangible VR training tool to train DMA-SR within the police context. The main input was derived from D2.2 and D4.6, mainly based on end user needs and experts' input (WP4 deliverables such as the Real Time Trainer Dashboard, see D4.5). The **SHOTPROS VR solution** is technically based on the VR training solution from the technology partner RE-liON and in an agile process (defined in D1.1) together with the development partner, the requirements from research and expert partners and particularly the needs of the end user partners, the solution was developed in a status even beyond the technical readiness level envisaged in the Description of Action (DoA) in order to make the field trials training sessions as realistic as possible and without the need to deal with low level prototypes. Nevertheless, some requirements exceeded the scope and resources of the project but were identified to deliver valuable input for a VR training solution considering DMA-SR training. Therefore, some features were developed in a separate experimental environment to execute studies and pre-user tests with this feature set. One of these was the need for more graphic realism (see later in the document). Moreover, the cost aspect of VR training solutions was of interest for the future exploitation of the VR solution (see D8.6) and therefore the experimental environment also included other hardware equipment to explore less expensive training options. But it is important to mention that the full DMA-SR approach is only valid for the SHOTPROS VR solution itself. The SHOTPROS VR solution now represents a **full-body VR setup**, for **high-end train-as-you-fight scenarios** in large spaces to enhance the performance of European police officers. It features a VR suit with sensory options, (direct) interaction, In-Action Monitoring (IAM) and After-Action Review (AAR), a general training framework and scenario creation and editing options.

With the SHOTPROS VR solution it is possible to train on a field of 30x30 meters (up to 100x70 meters) and use gym halls or similar locations available in almost all police training environments. A standalone wireless network operating within this training area allows for positional determination, 1:1 simulation of the scenario to the real-world expanses. Trainees wear the textile SHOTPROS Smart Vests (see Figure 4 for details and Figure 5 for system overview, green mark with #6) for tracking within the training pitch which is strapped around the trainee's body and also includes haptic feedback devices. Besides the head-mounted display for the VR experience, additional features such as the SHOTPROS tactical belt (including e.g. a replica gun), physiological

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measurement devices for the SHOTPROS stress assessment or communication devices (e.g. radio), are also part of the body-worn equipment.

Figure 4: Body-worn equipment SHOTPROS VR solution

The trainer has different options to follow the training, typically using the Trainer Station (#4) placed alongside the field is used for this purpose. Here the trainer can follow the action visually and with audio. Bookmarks can be set anytime to later find this event in time more easily. The trainer can communicate via microphone with (each) trainee, and the stress level can be monitored, and suitable stressors can be activated or deactivated according to the needs of the trainees. However, it is also possible for a trainer to wear a Smart Vest and participate in the training as an active user in form of the trainer or a role player. The SHOTPROS VR solution works with a client-server architecture, with the server running at the Exercise Control (EXCON) Station (#3) and the Smart Vests set up as clients (further information can be found in D5.1). The EXCON Station is used by a technical operator, who is usually the one who sets up the scenario and is able to make modifications throughout the training. For correct tracking, trainees need to be measured (height and arm span) and registered in the system before calibration. After the field-based physical training, the trainees gather at the Trainer Station (#4) for a debriefing session, the After-Action Review with the trainer. The trainer is given a variety of tools at this station to review the training from various angles and based on evidence and events (for detailed information on how to use the

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After-Action Review, see D7.5). Batteries carried in the backpack need replacement and recharging on a regular basis and therefore a Battery Charging Station (#2) should be placed in the vicinity of the training field. Scenario development usually happens before the actual training but if necessary and the need for ad-hoc scenario adaptions is given, this needs to be considered (#5).

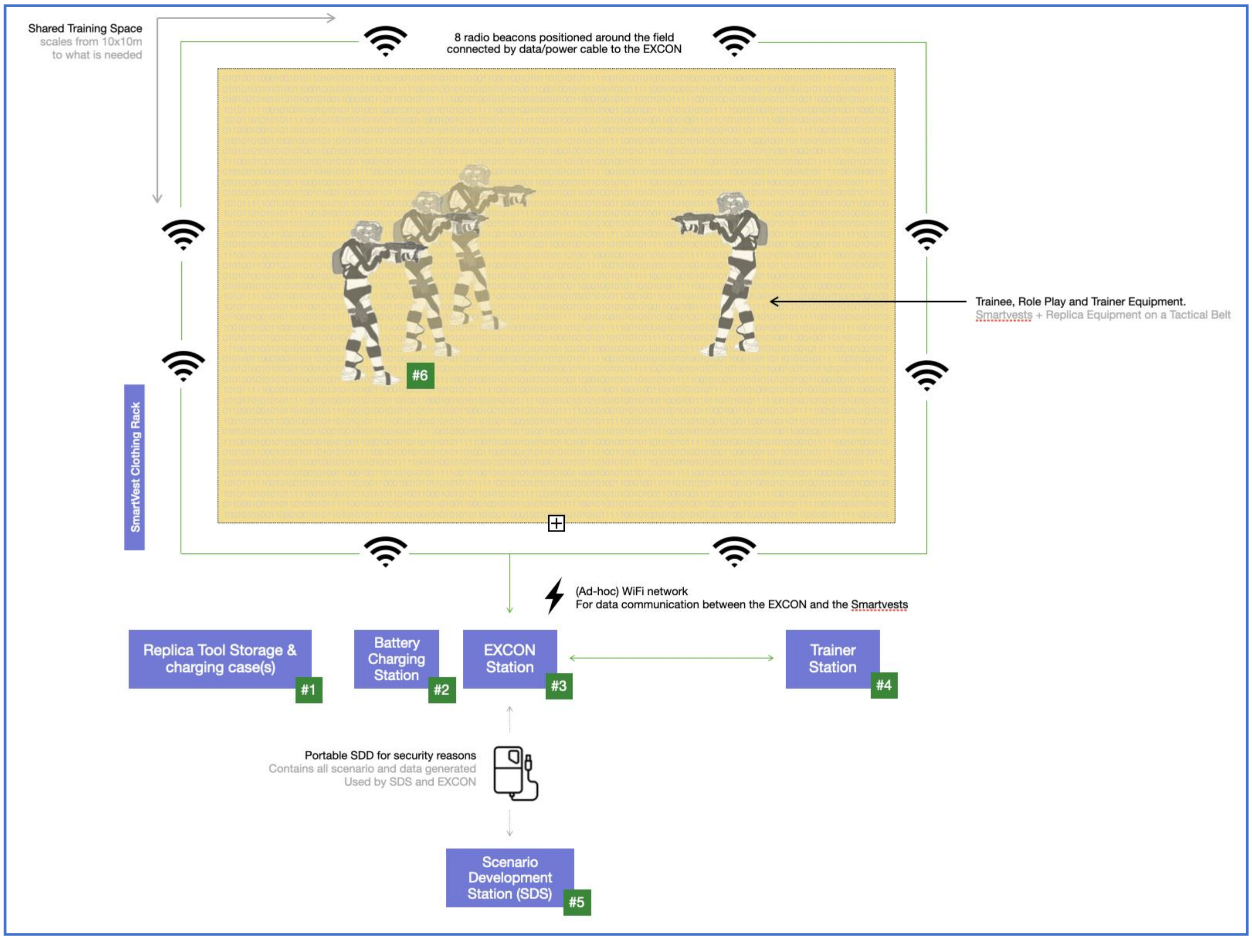

Figure 5: SHOTPROS VR solution setup components

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The SHOTPROS system uses Wi-Fi tracking and is not disturbed by sunlight. Therefore, it would be technically possible to operate VR trainings outdoors, especially if larger space is needed. The set-up of the system (indoor and outdoor) is done quickly within 1-2 hours. If already set-up, the system can be ready to train within 15 min.

Figure 6: SHOTPROS VR solution in use with Excon Station in the background

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4.1 Experimental environment - Compact VR Setup

For testing and prototype reasons, an experimental environment based on the Unreal graphic engine was developed. To be faster in set-up and also to test possible less expensive product versions for later exploitation, a simplified version based on off-the shelf hardware was implemented. Controller and VR glasses, enhanced with a tactical belt build the simple and quick solution, trainable in a 10x10 m area.

Figure 7: Experimental compact VR environment in use - Trainer Station in the background

This approach is not suitable for large scenario-based DMA-SR trainings and comes with several challenges such as realistic movement and tracking of tactical props, but the purpose was not to develop another DMA-SR solution but to test out features at a prototypical level and decide about the integration in the full version after end user feedback. The new and much more realistic graphic was very well received by the LEAs. Another very interesting aspect is the easy set-up for usage within police stations (the system is available “any” time and a trainer could join a training session from another location. Aspects like these are probably not a final solution, but the problem of too less training hours for police staff can be targeted with solutions like this. Training in a compact

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version could be seen as preparation for the bigger training sessions with "large" scenarios or to train easy low-level scenarios with a focus on regulations or other less stressful objectives.

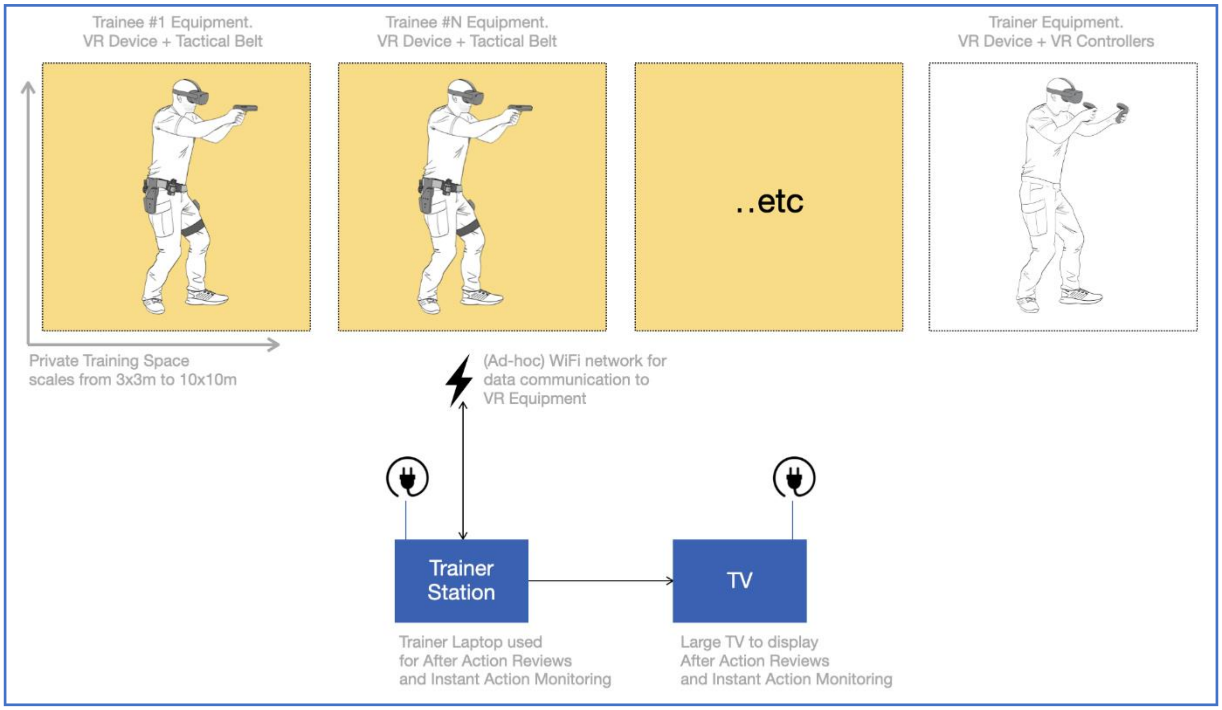

Figure 8: Compact VR setup schematics

Note on full body vs. compact version
For DMA-SR group training with train as you fight, there is no way around full-body tracking and tactical belts. But other content can also be covered and trained with VR, for which a simpler setup can suffice. SHOTPROS evaluated both approaches, whereas the focus is the SHOTPROS VR solution.

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5 Technical VR Guidelines

Together with suitable training curriculum for DMA-SR training (D7.5), the technology (hardware and software) and their interaction with the user, play a crucial factor for DMA-SR training in the VR and will be discussed in the following chapters. DMA-SR training comes with very specific requirements, which the SHOTPROS consortium has established throughout the project and will be discussed as part of these technical VR guidelines. In the following a separation of hardware- and software-related features is done. Nevertheless, most of the technological features represent an interplay of both and hardware typically needs software components to be reflected in the VR and to be experienced by a user. But the user view on this topic was the relevant factor for us as users tend to simplify the approach by “I can touch it” so it is hardware and “it’s in the training program”, so it is software. This separation made it easier during the course of the project to identify and discuss needs and features with end users.

5.1 Hardware Guidelines

Since DMA-SR training is very physical and realistic movement plays an important role (see D7.4, the scientific HF model), movement should be as limitless as possible. This is also supported by the scientific model (see D3.2) which always combines decision making and acting (which is always a bodily action) as a combination and not separable. Movement is therefore the base of DMA training.

Hardware consequently plays an important factor in successful VR training as some of the hardware is body-worn by the trainees (head mounted display, VR backpack PC, stress measurement wearable, etc.) or used within the training as a tool (like the tactical belt) or by the trainer to monitor or steer the progress of the training scenario (trainer station with large touch screen, controllers, etc.) and therefore comprises different needs including technical requirements, usability, user experience and ergonomics. This means that hardware is needed that supports the unrestricted freedom of movement and realistic use of the gear, even in the virtual world, and that comes as close as possible to reality – “train as you (de-escalate the) fight”.

It should not be forgotten that the training is usually carried out in groups, as they are also done in real professional life. Usually these are two or three police officers, but if an additional team is ordered for support, there are already four to six, and if role players are also used to represent the attackers, the number of users quickly rises to eight.

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Another important feature is haptic feedback, e.g. when being hit or touching a wall, increases immersion and makes behaviour more realistic. How large the operation area is (public square, shopping centre) also determines the area that has to be covered in the VR system and that has to be accessible with natural movements.

Based on these requirements, in the following the components of a VR system with VR headset, tracking system, spatial sound, locomotion, graphics, non-player characters, etc. are described and advice is given on what to pay attention to in order to meet the requirements for DMA-SR training.

5.1.1 VR Headset

For a VR experience, hardware in the form of VR glasses is needed. Two high-resolution displays in the headset create digital images that react with a coupled sensor system. When the user moves his or her head, the sensors register the change in position and adjust the continuously generated images accordingly to the view. In contrast to a normal screen, a VR headset provides a separate image for each eye in order to achieve the desired stereoscopic depth effect. In addition, since the display area is projected onto a large part of the human field of vision, VR headsets require very high resolutions to achieve the same pixel density and thus the graphic sensation of a corresponding screen. Current headsets offer up to 4K per eye. To ensure immersive, i.e. "smooth", movement within the virtual environment, all calculations must be done in real time with very short latency. This should be 7 to 15 milliseconds, which corresponds to about 70 to 140 frames per second and is also achieved by current VR headsets (e.g. HTC Vive Pro 2, HP Reverb G2, Valve Index, Varjo Aero). A powerful computer is required to achieve this frame rates with high resolutions.

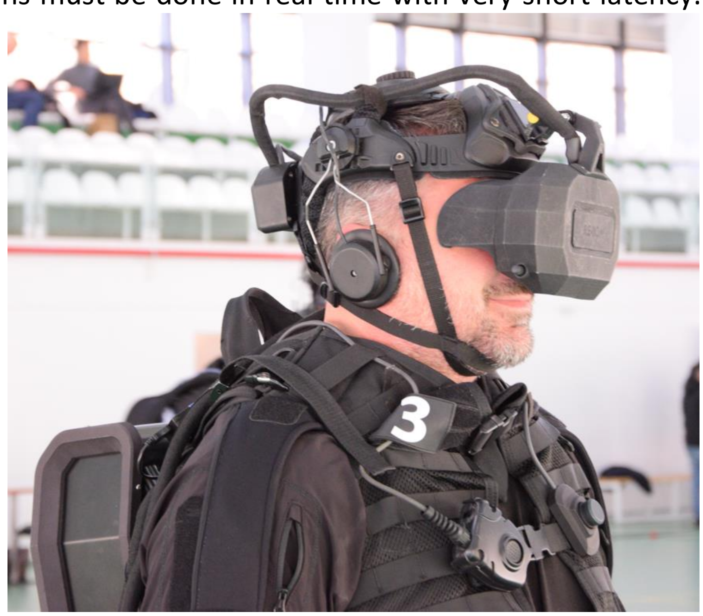

Figure 9: SHOTPROS VR solution - headset & sound device, radio communication

The professional Skull Crusher headset (see Figure 9), used in the SHOTPROS system, carries the head mounted display (HMD), headphones and microphone for radio communication with colleagues, the trainer and the operator behind the Exercise Control Station (EXCON, Figure 5, mark #3).

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The device ensures that every trainee can set the distance and tightness on his/her head according to their own preference. The HMD is the VR display device that delivers the visuals for the virtual environment. The headphones are also used for the 3D environmental sound and stressor sound cues.

Note on VR headsets
Requirements for high resolution, realistic graphics and avatars need sufficient computing power. Either there is a PC at the back or a wireless streaming solution, which will certainly become more popular in the future. A powerful PC is still needed, but the freedom of movement is greatly improved. Alternatively, stand-alone headsets can also be used for some training. In any case, frame rates of 70 to 140 frames per second provide a pleasantly smooth immersive experience. A really important aspect is the wearing and visual comfort, the headset should be light and well balanced and well fixable. All this makes longer training sessions possible without any problems. In SHOTPROS, there are the full-body VR versions with the PC at the back and a stand-alone VR headset with limited capabilities.

5.1.2 Spatial Sound

Spatial sound in VR is important for the training effects (where is the threat and is it a relevant or irrelevant stimuli – see D7.5) and should not be neglected when evaluating different systems. Sound is an important factor for overall immersion but also to localise an event source or stress factor. Especially for police officers it is one of the senses used to identify potential threats and their location or necessary space between the threat and the trainee (self-protection).

Note on Spatial Sound
Hearing and localising noise and voices is an essential part of the training. Accurate 3D reproduction of sound is important.

5.1.3 Multi-User and Interaction Modalities

When training DMA-SR as a team, **communication** and **interaction** is a key component of a VR training system. Interacting and communicating is done on different channels:

- team internal communication

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- communication with external actors like mission control or
- communication with non-player characters or the human perpetrator inside the VR scenario.

Communication does not only mean communicating by speaking, especially in the context of police work. Certain situations demand non-verbal forms of communication, for example hand signs or body contact.

Team internal communication: For communication between trainees and trainer with trainees, a headset and microphone are required. Some VR headsets have a headset and microphone already included. Otherwise, additional devices are required for communication and integrated into the VR system. These usually take the form of headsets with an integrated microphone. Ideally, this form of communication is also spatialized, meaning that the farther away another user is, the quieter the voice will sound. Additionally, communication over distance can be realised by including a prop radio, that once activated allows for communication over a longer distance. Within the SHOTPROS system, participants wear a headset with an integrated microphone, that is directly connected to the backpack PC. The headset has passive noise-cancellation, so that only sounds from within the simulation (including the voices of team members, the perpetrators and NPCs are heard).

External Communication: In addition to the communication within the team, it is crucial to have a communication line to the operator of a VR training or the trainer. The same devices can be used, but it requires some additional software requirements. For one, the operator/trainer must be able to selectively talk to singular trainees, in the case of e.g. technical difficulties or explanations, but must also be able to switch to talking to the full team. If a role-player is present in the VR training scenario, the operator/trainer must have the possibility to give instructions only to them. These requirements are all met in the SHOTPROS VR solution, allowing for easy and targeted communication by the trainers with all trainees or subgroups of them.

Non-verbal communication & interaction: Next to verbally communicating, tactical operations also require non-verbal forms of communication. When a perpetrator is nearby, and should not be alerted of the officer's presence, hand signs and body contact are valuable ways to communicate intentions of movement or tactical manoeuvres. Simple hand signals are possible with all VR systems, as the hands are either tracked individually, or hold controllers that are tracked. For a finer granularity of signs, fingers can be tracked individually in more modern HMDs, which are equipped with inside-out tracking through their onboard camera's. This offers automatic finger and hand tracking when in view. This capability can be connected to the avatars of the trainees and instructors

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in VR enabling non-verbal communication using finger gestures and manipulation of objects, like picking up objects or opening doors. This technology though is still in development and needs more time to become commercially viable for VR police training.

Body contact is another form of non-verbal communication. Moving as a team in a tactical operation requires police officers to touch the shoulder of the colleague in front of them, enabling securing of all angles while not losing team cohesion due to the colleagues not being in sight. This requires a VR system, where all trainees train in the same space, as realised within the SHOTPROS project. In systems where each trainee is training in a different spot, this is not possible and therefore a limitation of these systems.

Note on Multi-User and Interaction Modalities
Group communication and interaction is a key component of training DMA-SR. The communication channels and modes that exist in reality must be supported by the VR system for team internal, external, verbal and non-verbal communication and interaction.

5.1.4 Tracking for VR Headset, Body, Devices and Objects

Tracking allows a VR system to **detect the position** and **orientation** of devices and parts of the user's body. Many interaction devices in VR are equipped with tracking device to measure the position and orientation of the device or the part of the body to which they are attached. In the case of an HMD, this is how the position and orientation of the head is tracked. This information determines the user's location in the virtual world and controls which part of the world is shown on the HMD display. Tracking devices attached to the hands, legs and feet, known as full body tracking, measure the position and orientation of the respective body part. Based on this information, the user's posture and movement can be realistically reproduced and displayed in the virtual world. Tasks that require skilled handling, or especially in a training session with several trainees, this mapping plays an important role to increase immersion.

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Figure 10: SHOTPROS VR solution – body tracking sensors in Smart Vest (e.g. white square on palm)

Tracking devices measure the position (x-, y-, z-coordinates) and the orientation (yaw, pitch, and roll), i.e. the so-called 6-degree-of-freedom (6-DOF) in relation to a reference point or condition. There are various technologies for this purpose, which generally consist of three components: A source that generates a signal, a sensor that receives the signal and a controller that processes the signal and communicates it to the VR system. Depending on the system used, either the source or the sensor is attached to the body and the complementary component is mounted at a fixed point in the environment and serves as a reference point.

Essential criteria here are **tracking precision**, **update rates** and the **time delay** between the real position or movement and the communication of position and orientation to the VR system. In this case, there is a **threshold value for time delays of 50 milliseconds** at which the delay becomes perceptible and the VR experience is negatively affected. The update rate indicates how many measurements are reported to the computer. Typical **update rates are between 30 and 60 updates per second**. Precision depends on the resolution and accuracy of the capture device being used. The resolution is usually fixed for a given device; the accuracy usually decreases with the distance of the sensor from the source. The **range** of a tracking device indicates the **maximum distance between the sensor and the source** in which the position and orientation can be measured with a certain accuracy.

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Sensitivity to environmental factors or interference limits the effectiveness of tracking devices. Current tracking devices are based on electromagnetic, acoustic, mechanical or optical technology. Depending on the technology used, they can be sensitive to large metal objects, radiation from screens or other wireless networks (Wi-Fi, 5G), strong sunlight, various noises and objects between the source and the sensor. **Careful consideration** should be given to these factors **when selecting the physical environment**.

The technology used in popular consumer products is active optical tracking, meaning that the sensor or source is connected to the device being tracked. In passive tracking, the target is monitored remotely by cameras. Usually, numerous cameras to avoid occlusions and to obtain a stable continuous position information. The following is an overview of the different optical tracking methods available.

5.1.4.1 Optical tracking

Optical tracking uses cameras to determine position and orientation based on computer vision algorithms. After an initial calibration of the cameras, the distance to the object and its position in space can be determined. Optical systems are reliable and relatively inexpensive, but calibration can be difficult. The system also needs uniform lighting conditions without occlusions, otherwise it will give erroneous results.

Optical tracking can be done either with or without markers. When tracking with markers, targets with known patterns serve as reference points. The markers are searched for in the camera images with algorithms and the position of the object is evaluated. Markers are either visible, e.g. printed QR codes, or, as is often the case, infrared LEDs built into the object. The camera and marker are switched on and off synchronously, making it easier to fade out other IR lights in the tracking area. Markerless tracking uses the natural features of the environment and objects to determine position and orientation. However, they play a subordinate role in rapid and precise position tracking for VR.

Optical tracking is differentiated into two approaches, outside-in and inside-out and explained in the following.

Outside-in tracking
In this method, cameras are placed at stationary locations in the surrounding vicinity to track the position of markers. Multiple cameras provide different views of the same markers and this overlap allows accurate measurements of the position of the device. The use of markers with IR

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LEDs is the most mature method and is used not only in VR but also in motion capture technology for movies. However, this solution is space-constrained as objects must be in constant view of the cameras.	
Pros: • Accurate position tracking, can be improved by adding more cameras • Lower latency than inside-out tracking	**Cons:** • Occlusion, cameras need direct line of sight or else tracking will not work • Necessity of outside sensors means limited play space area

Table 3: Outside-in tracking, pros and cons

Inside-out tracking	
Here, the camera is on the moving object or headset and detects where it is currently located in the room. This method is used, for example, in headsets, where several cameras are installed that point in different directions in order to capture the entire environment. This method can work with or without markers. A common example for active markers is the Lighthouse system of the HTC Vive. External Lighthouse modules generate an infrared laser array in horizontal and vertical directions. The sensors on the headset or controllers record the times at which the laser passes them and can calculate the position from this. Markerless tracking, as with the Oculus Quest, does not require any assistive devices to be placed in the exterior surroundings. It uses cameras on the headset for a process called SLAM (Simultaneous Localisation and Mapping), which creates a 3D map of the environment in real time. Machine learning algorithms then determine where the headset is positioned within this 3D map and use feature recognition to reconstruct and analyse the environment. This technology enables headsets that do not need to be connected to any external computers or sensors. Modern HMDs equipped with inside-out tracking through their onboard cameras offer automatic finger and hand tracking when in view. This capability can be connected to the avatars of the trainees and instructors in VR enabling non-verbal communication using finger gestures and manipulation of objects.	
Pros:	**Cons:** • More on-board processing required

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• Enables larger play spaces, can expand to fit room • Adaptable to new environments	• Latency can be higher

Table 4: Inside-out tracking, pros and cons

As an alternative to optical tracking, there is Wi-Fi tracking.

5.1.4.2 WiFi Tracking

WiFi can also be used to determine the position. There are several methods that work on signal strength, signal runtime or angle of arrival. With signal strength, only accuracies of 2 to 4 meters can be achieved and is not suitable for the precise requirements of VR. By measuring the signal round trip times, a higher accuracy can be achieved and is suitable for VR tracking.

Wi-Fi signal round trip time (RTT) for tracking	
With the signal round trip times (RTT) several access points are used for the calculation of the location. A single access point is not sufficient for the exact determination of the location, rather several stationary WiFi access points are necessary. This involves signal propagation times in the pico-second range and requires precise measurement. Determining the round-trip time is easy to implement because it consists of only one handshake. However, the remote stations must have a sufficiently accurate system time. Multi-stage handshakes can increase the accuracy here, in the course of which both remote stations exchange time stamps (Fine Time Measurement, FTM). The Wi-Fi Alliance has introduced the "Wi-Fi Certified Location" certification for this purpose. Under the name "Next Generation Positioning", the IEEE standardises this function under the designation 802.11az.	
Pros: • A major advantage of this method is that, in contrast to optical tracking, it does not require a clear view. Walls, people or objects are transparent to Wi-Fi. • WiFi Tracking is insensitive to room illumination or texture and it can work in the dark or twilight or extreme light.	**Cons:** • Higher setup and calibration efforts

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• Can cover large range and accuracy remains constant and does not increase by distance to the sensors.	

Table 5: WiFi tracking, pros and cons

In order to train large operational areas with multi-users, the SHOTPROS VR solution uses Wi-Fi for tracking. It covers large areas with constant accuracy, and it is technically possible to operate VR trainings outdoors, especially if larger space is needed. This also has the advantage when tracking the tools of the tactical belt occlusion by the human body is not a problem.

Note on Tracking for VR headsets, body, devices and objects

The most commonly used tracking method used in VEs today is optical tracking. This is done using either image features of the environment or markers, or alternatively with active markers as utilised in lighthouse systems. These systems are reliable and relatively inexpensive, but also needs uniform lighting conditions. An alternative is the use of Wi-Fi for tracking. As it passes through the body unhindered, it has no problems with occlusions, is independent of lighting conditions and can cover large areas also outdoor. On the other hand, there is an extra effort in calibrating and setting up the system. The SHOTPROS VR training system uses Wi-Fi tracking to cover large areas up to 70 x 100m with full-body and object tracking for the tactical belt and support all features required for DMA-SR training. The experimental setup uses a consumer VR headset with optical inside-out tracking providing a trainable area of 10 x 10 m, additionally also object tracking for the tactical belt but no body tracking.

5.1.5 Locomotion

Locomotion refers to the technology that enables movement from one place to another within VEs and is an extremely important factor when it comes to the level of embodiment and immersion in VR training. It can be distinguished between physical (actual walking) and artificial locomotion techniques (see Figure 11). Physical locomotion is the preferred option for DMA-SR training, ideally in a 1:1 simulation of the scenario to the real-world (1 meter walked represents 1 meter in the VE). Most VR solutions have some sort of restriction when it comes to the size and space of the VE. VR

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scenarios should be designed to make this restriction seem as natural as possible by, for example, adjusting the size of a building or room to the actual training space available.

Artificial alternatives, such as controller-based “floating” or teleportation, have been developed and improved over the past decades but should not be considered for tactical police training and DMA-SR. Within the SHOTPROS project both artificial options have been tested (see experimental environment at the beginning of the document). For most LEAs it was not a feasible option for training, because movement and natural behaviour as well as the estimation of distances, spaces and the positioning of the trainee in contrast to the colleagues, perpetrator(s) and/or victims is of high importance and needs to be replicated in the VE. A considerable amount of test subjects have also experienced motion sickness during artificial movement options and reported a very low level of immersion.

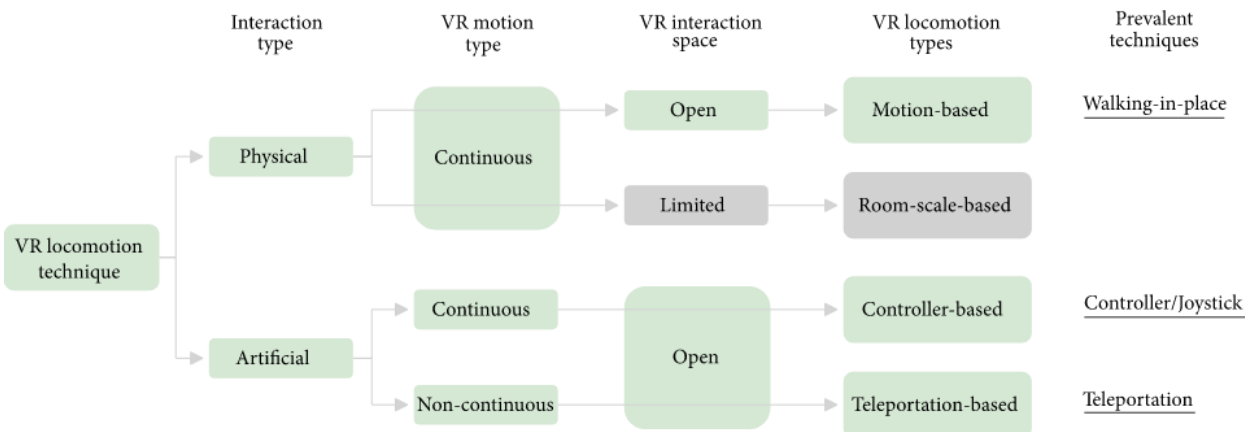

Figure 11: Locomotion techniques used in VR (Source: https://www.hindawi.com/journals/ahci/2019/7420781/)

Note on Locomotion
Natural locomotion in VR is a must for DMA-SR training.

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5.1.6 Tangible Interaction and Devices

Tangibility describes aspects of VR, that enable an interaction with the virtual environment with sensory modalities that go beyond the visual and auditory. Examples would be physical objects that are tracked in space and have a virtual representation, allowing the user to pick-up/touch the object both in reality as well as in VR. This is also an intensive interplay of hardware and software, but as the hardware is the crucial point to make it immersive, we listed it under hardware descriptions.

Tangible or physical interaction in VR represents a huge potential because tangibles naturally provide rich haptic cues which are often missing in consumer VR experiences. In VR, users often manipulate virtual objects through generic controllers which decreases immersion. But when tangible interfaces are used, the interaction with the virtual world feels more natural, intuitive and realistic. Additionally, when the tangible interface is an actual replica of a virtual object, training exercises truly reflect daily working practices. Learners can repeat tasks virtually with the physical representations of their real tools, building muscle memory that helps with retention of learning, which can then be implemented in real life. This topic is only partially valid for the interaction with weapons (pistols and long-guns) as there the muscle memory is trained with precision to one individual tool. But for other police gear like flashlights, pepper-spray etc. this can be applied and is very helpful).

In general, physical VR can be divided into different tiers:

- **Tier 1: Passive Haptics**
  In this tier, haptics are not tracked in space, but are positioned so that it corresponds with a virtual object. An example would be placing a little bridge in the spot corresponding to a bridge between two roof-tops in the virtual world. This can be a cheap integration of physical VR that can already lead to a high realism.
- **Tier 2: Tracked haptics**
  Tracked haptics are passive haptics with a tracker. This enables the virtual corresponding object to move, when the physical, tracked object is moved and allows for a basic interaction with the virtual world.
- **Tier 3: Tracked haptics + buttons**
  Tier 3 is reached, when a tier 2 physical prop is enhanced with buttons or triggers.
- **Tier 4: Tracked haptics + Additional Input / Output**
  Tier 4 haptics offer additional feedback or input modalities, like track pads or vibration.

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- **Tier 5: Custom designed active haptics**
  These are the most advanced physical props. They contain electronics and offer features from all tiers below and are custom designed. An example would be the gun replica within the SHOTPROS project, which was 3D printed and has integrated electronics, which allows for a realistic shooting experience.

Within the SHOTPROS project, the Smart Vest, the full body haptic feedback suit (see chapter 4) and the tangible tactical belt (see chapter 5.1.6.1) have been implemented successfully, allowing for a more immersive, realistic experience in the VR training. For even more intense tangible interaction, we have also completed studies involving light electric shocks as pain feedback for being attacked during the training (see chapter 6.2.2). In the training context, haptic/tactile feedback (vibration on touch) provides the illusion that trainees feel structural elements like walls, doors and other furnishing, or when being virtually hit by bullets, stun gun, baton or pepper spray. One of the most important reasons to provide tactile feedback is to provide trainees with feedback once they are touching a wall. Imagine a trainee walking backwards to de-escalate a situation through creating more distance while facing forwards to keep an eye on a perpetrator. Without tactile feedback, the trainee could straddle a virtual wall without feeling it and end up in another space. This would immediately disorient the trainee, break immersion and requires a pause in the scenario.

Note on Tangible Interaction

For VR police training, we recommend considering the following points:

- Depending on training goal, physical props can be essential to build up muscle memory and not learn wrong procedures. This can even start at tier 1 passive haptics.
- A future system should have realistic weapons and tools, ideally with force feedback, the real weapons' shapes. Tier 5 haptics are recommended in this domain.
- For weapons and tools, we recommend checking the tracking in detail. A congruent experience (aiming, shooting) is crucial in this field, so that muscle memory can develop and acceptance of the trainees is secured.
- For increased behavioural and psychological realism, pain stimuli are recommended, as they intensify dangerous situations in VR and lead to trainees behaving more realistically. For example, we found that trainees kept their distance to a perpetrator much better, when they knew a light shock could be administered should the perpetrator shoot them.

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5.1.6.1 Tactical Belt – Physical Prop

Physical props play an important role in scenario-based training and there is a strong need from LEAs to have gear that is as realistic as possible (in size, weight, haptic) in VR training as well. To transform a VR training system into a the SHOTPROS VR solution, a VR police training system, the tactical belt was developed, as one of the most significant innovations in SHOTPROS.

SHOTPROS tactical belt is an adaptation of a physical tactical belt, modified to interact and have a visual representation in the virtual environment.

Figure 12: Tactical belt including innovative tools developed for SHOTPROS

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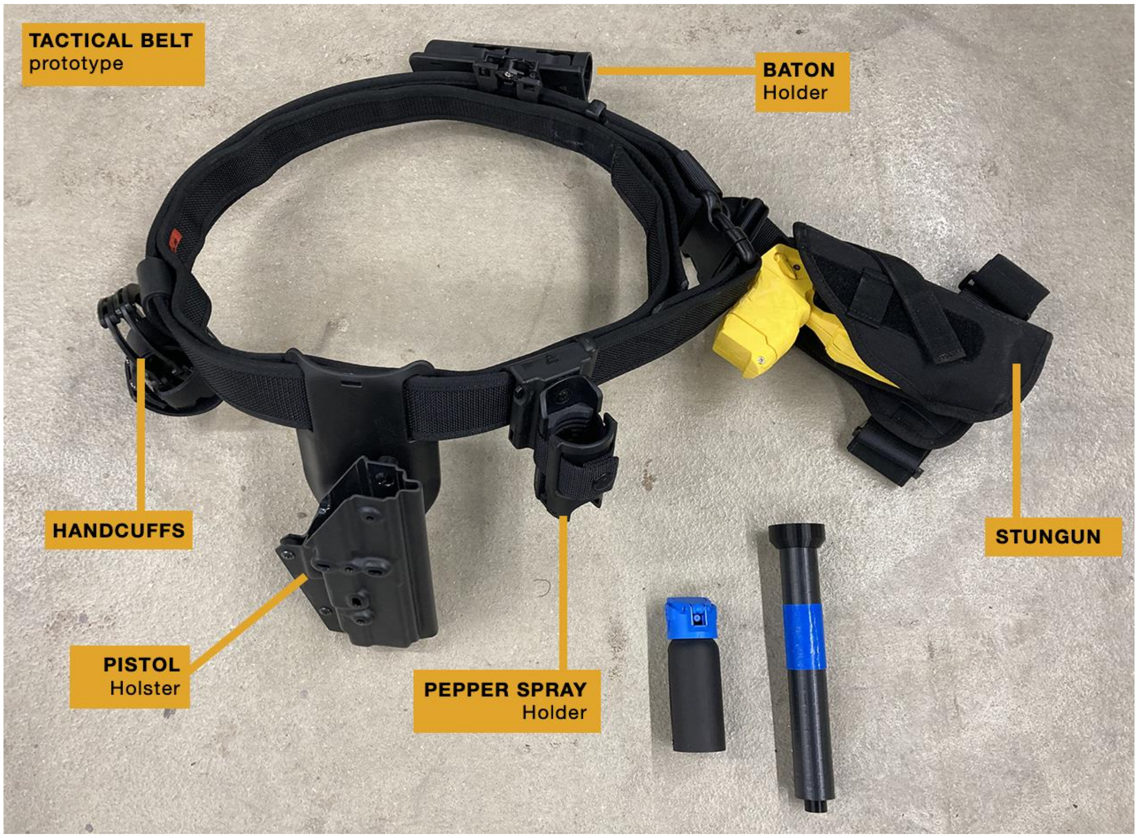

Figure 13: SHOTPROS Tactical Belt

The SHOTPROS belt is equipment with the following components:

a) **Handgun** – realistic model (size, form and weight as well as realistic behaviour regarding trigger pulling and changing of magazine)
b) **Pepper spray** – can be set to infinite spraying capacity or need to re-fill after a certain amount of usage. If the pepper spray is used inside a room, the trainee will have limited visibility for a short amount of time. If used on an NPC, they need to react accordingly (limited visibility, hands in front of their eyes). An affected role-player should also have limited visibility and information that he was affected by pepper spray so he can react accordingly.
c) **Electroshock gun** – this tangible device fires a single or a double shot (trainers can select mode for each trainee or on group level).
d) **Baton** – The tangible device used has the length of a retracted baton and can be virtually expanded

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e) **Handcuffs** – to handcuff an avatar the virtual handcuffs need to be held towards their hands, a "success" message will be displayed when done.
f) **Flashlight** – the light is on as soon as it is taken out of the holster and can be switched off/on.

Each usage can be tracked in the In-Action Monitoring (IAM) and AAR (see later in the document).

Developers and trainers should take into consideration that it requires practise to use virtual equipment. When trainees use it for the first time they will need to go through a tutorial and be given the opportunity to practise as the interaction between the tangible device and the virtual reflection needs to get used to.

Note on Tactical Belt
A VR tactical belt is an adaptation of a physical tactical belt, modified to interact and have a visual representation in the virtual environment. This belt contains the same tools the police officers use in real life and provide realistic training – train as you fight.

5.1.7 Multisensory Experience

Beside sight, hearing also touch and smell sends information to the brain to perceive the world around. Touch comprises several distinct sensations communicated to the brain via special neurons in the skin. Pressure, temperature, light touch, vibration, pain and other sensations are all part of the touch sense and are perceived by different receptors in the skin. Another sense is the sense of smell, which plays a role in the perception of the environment. These senses also contribute significantly to the VR experience and should therefore also be utilised for this purpose. In particular to realistically materialise stressors for DMA-SR training in the VR. That should enhance the effect, dangers should be perceived mor threatening to increase the stress level of trainees.

Within SHOTPROS, a prototype for administering multi-sensory stimuli was created and tested during the FTs, including an olfactory device[1], radiant heater and wind devices like a fan to improve environmental threats and light electroshock administering devices[2] to simulate injuries caused by weapons. The prototype and the corresponding studies are further described in chapter 6.2.

[1] https://ovrtechnology.com/
[2] https://pavlok.com/

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The multi-sensory elements are listed here in Table 6 and the effect that is intended to be achieved for VR training is described.

Stimuli	Effect
Heat	In the context of police training, heat could be of use as a simulation of e.g. very hot weather which would act as an additional environmental stressor, or as an augmentation of fire or explosions. This will result in a greater sense of urgency by the trainees to evacuate, as well as increased scores of perceived pressure and adaptive behaviour to avoid the source of danger.
Wind	In the context of police VR training, wind could be used to simulate cold and stormy weather, one of the identified stressors. In combination with heat, sensations of a sudden heat wave by an explosion can be simulated.
Pain	In high-risk situations we suspect that the potential presence of pain has a detrimental effect on behaviour and the amount of caution. A VR training for these situations thereby lead to more realistic behaviour of the trainees when there is a chance of pain stimulation. General pain research suggests that pain commonly triggers avoidance behaviour when encountering a potentially pain-inducing threat. On the other hand, pain is also considered to serve as a motivational factor to act. Both highly relevant factors in police training, especially in virtual environments, to make virtual offenders and weapons more realistic and not misleading trainees into mistaking a serious training environment with non-consequential computer games.
Scent	For perceiving certain threats, olfactory cues are crucial. For example, a puddle of liquid can be water or gasoline, but look the same. With an olfactory device integrated into VR, the threat of gasoline catching fire can be perceived before by noticing its smell. Additionally, it can play more of a supplementary role in creating ambient smells, that can be perceived as stressors: the smell of sweat of a big crowd for example can be a subtle uncomfortable element in the virtual environment, that can impact the perception of the trainee and therefore prepare them better for the real situation. Depending on the training goals, we recommend a future VR system for police training to include olfactory devices.

Table 6: Multi-sensory stimuli and intended effect.

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Note on Multisensory Experience
The addition of multi-sensory elements like heat, wind, pain and scent to particular stressors shows great potential for making the VR training experience even more realistic and threats more stressful. It enables the detection of environmental threats which are not visible and increases the engagement in the training scenario.

5.2 Software Guidelines

VR technology means the virtualisation of training and besides the VR hardware with headset, tracking, tangible interaction and multisensory experiences, it needs the software to create the digital content for the training, to make the graphics and animation realistic, make virtual characters show human behaviour and it needs software to control the training execution, assess the stress level of trainees and to support the AAR with extensive review capabilities and performance KPIs. In the following, these components are described and guidelines are given. A complete overview and description of the components of the VR training system can be found in D5.1.

5.2.1 Graphics, Animation and Movement

To render the visual world with the necessary graphics quality and as little latency as possible, training in VR requires sufficient computational power. To see the image as clear as possible and almost in the moment it happens in real-life (e.g. movement of a colleague or a perpetrator) was one of the most important requirements of end users towards a relevant DAM-SR training solution (see D4.6, requirements). How immersive the user experiences the VE is influenced by the graphics and animation.

The following factors have been identified as important by the SHOTPROS end users:

- Realistic, immersive graphics with realistic colours and textures
- Correct kinematics of movement
- Detailed visualisation of indoor and outdoor (vegetation, urban clutter, etc.) scenarios.
- Large selection of building fronts, vehicles for scenario building and diverse avatar skins.
- Animations of face and body that are able to show emotional and physical state (triggers for police).

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- Sufficient resolution to be able to spot from a distance if a character is carrying attributes and what, (un)armed and if armed, type of weapon.
- Speech: slurry speech versus clear speech, a trigger of use of intoxicating substances.
- Large enough environment to enable a variety of scenarios that are difficult or unsafe to train in real life.

Although the SHOTPROS VR solution offers a sufficient quality to provide users with an immersive training experience throughout the project, the need to further develop features related to graphics and animation has been identified. A potential graphic-related solution for the SHOTPROS training system (i.e. switching to the off-the-shelf available 3D computer graphics game engine Unreal Engine) has been investigated, tested and an experimental system as a compact VR setup was developed (see 4.1) to enhance the graphic experience and test out how this could be introduced in the SHOTPROS VR solution.

Note on Graphics, Animation and Movement
Simulations delivered in virtual reality require a balance between contextual sensory (graphics, sound) and behavioural details (animation, movement) to maximise the transfer of simulated tasks, knowledge, skills and behaviours to real-world environments.

5.2.2 Non-Player Characters

A non-player character (NPC) is a character that is controlled by the VR system or by an operator. For scenario-based police trainings we differentiate 3 major NPC types in the VR:

1. Individual NPCs with **automated** behaviour and reactions according to an underlying concept of pre-defined reactions
2. Individual NPCs with **pre-defined** behaviour and reactions that can be selected additionally on 1-click by a user (Trainer Dashboard, Excon Station, VR view of the trainer)
3. NPCs as “background noise” with **simulated** crowd reactions and behaviour

To train relevant skills for first responders in scenario-based trainings, human interaction is necessary. In real-life scenario trainings, role-playing is often time consuming, costly and cannot cover the diversities of characters (age, gender, appearance, disabilities, size, minority, reactions,

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behaviour etc.) relevant for successful and realistic trainings. Therefore, computer-generated NPCs play a crucial role in VR training. NPCs offer a great solution to this challenge if their behaviour and reactions are portrayed in a realistic manner. All aspects of interpersonal communication and engagement, including voice (volume, tonality), facial emotions (friendly, furious), posture and movement, gesturing with the arms and hands, and maintaining or not maintaining interpersonal distance, are deciding elements in how realistic NPCs appear to the trainees. Reaction to the police officers with a realistic attitude (polite, rude, restrained or violent) as well as social interactions between NPCs add to the authenticity of the virtual training.

However, a reactive NPC that covers all these components is hard to implement and would require facial expression and speech recognition, language processing and the interpretation of movements. Due to limitations in technological off-theshelf solutions and resources within the project, the SHOTPROS consortium had agreed not to implement completely realistic artificially automated NPCs in the SHOTPROS solution. As a go-to solution, it was implemented to create a **predefined set of reactions** that is applied to the NPCs by the operator or trainer **before** (definition phase and **during** (as quick reactions towards the actions of trainees) the **training**. For the set of reactions, it is possible to start with various standard reactions (approach, keep distance, friendly welcoming, take a more offensive position, etc.) and extend them as the system is used and evolves. By sequencing the reactions, it is possible to create a more complex set of behaviours. Ideally these reactions could be triggered automatically by the system, however, further development in behavioural and speech recognition is required in order to make this reality. Language should be considered at this point as well. For example, if the system is built in English but training language of the LEA is different, NPCs might not be able to respond in the local language required without additional development efforts.

To test out even more detailed NPC reactions, the experimental SHOTPROS environment using the unreal graphic engine, also tested out the meta-human approach with more detailed facial expressions, the option to keep eye-contact and more human gestures and movements. This again enhanced the immersion by the end users and should be integrated within the SHOTPROS VR solution. Although role-player already enhance the immersion of a situation, the facial expression of feelings in addition to the voice with lip-synchronisation is also beneficial for the virtual appearance of role-player characters and would enhance the immersion of the complete solution.

However not only behavioural factors are important when it comes to a realistic imitation of a person, the graphical visualisation of NPCs has also been identified as crucially important. For

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example, clothes of characters (e.g. ripped shirt) or injuries (e.g. a black eye or cut skin) help police officers when assessing the situation. Detailed information on requirements can be found in D4.6.

In several SHOTPROS field trials the addition of scent to enhance realism has been tested and evaluated. For example, a perpetrator that smells like urine and alcohol, representing a homeless person. The feedback from users has clearly shown that adding scent can significantly improve the experience and help officers in the process of identifying the level of threat an NPC represents. See chapter 6.2.2 6.2 for study and results concerning the addition of scent to VR police training.

Note on Non-Player Characters
The great advantage of VR is the representation of a large variety of virtual persons to make scenarios appear more complex and stressful. The realistic interaction with NPCs poses high challenges (recognition of speech, emotions, body posture and movement) and can only be realised to a limited extent even with AI. Predefined behaviour patterns are usually used and triggered automatically or manually. It is also used in the SHOTPROS VR training system.

5.2.3 Role-Player Character

In the SHOTPROS VR solution, role-player characters can be used as an addition or alternative to NPCs. However not all VR platforms offer this feature, it is rated as very important by LEAs to re-play realistic behaviour and interaction with human beings (see D2.2, first requirements workshops and D4.6, requirements backlog). A role player-character is a virtual character whose actions, behaviour and communication are controlled by a real person. This feature offers the opportunity to combine the advantages of a virtual character (visualisations of a variety of different characteristics such as age, gender, appearance, disabilities, size, minority etc.) and realistic behaviour and communication (executed by the role player). Especially in police training, where instead of following exact step-by step instructions (like in the medical sector, where the treatment of a patient needs to follow clear rules) the decision making and acting of officers need to be done within a framework of law and regulations and react much more on the individual behaviour of the perpetrator and the surrounding victims and bystanders, the involvement of real persons is still important for DMA-SR training.

Simple training scenarios or parts of the training can be done with NPCs only, but with the current technical standards available, role-players need to be part of the DMA-SR training. Within the

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SHOTPROS FTs, one per training session was sufficient (see D7.5). They can be used to steer scenarios, escalate situations and act as additional stressor for trainees. Feedback given by trainees who trained scenarios with and without role player-characters indicated that they also have a strong influence on the realism of the training environment.

Note on Role-Play Character
The role-player character feature combines the advantage of a virtual character (visualisation of a variety of different characteristics such as age, gender, appearance, disabilities, size, visual minority-reflections, etc.) with realistic behaviour and communication. It is the best method to train verbal de-escalation realistically and is supported by the SHOTPROS VR solution.

5.2.4 Trainer in VR

In the SHOTPROS VR solution, the trainer can participate (when wearing the training equipment) in the virtual environment in an active way as a role-player or in his/her role as the trainer (with a trainer avatar marked with the trainer vest as usual in real-life) or even turn invisible to the others in the scenario and follow the action live and on the spot. This offers the trainer a full immersive experience of the training and another view on the actions of the trainees as he/she is actually in the virtual world and not viewing it from outside. Another option in the SHOTPROS VR solution for the trainer is (if in the scenario) to take over any NPCs and control them like a role-player by physically acting like this NPC or to take over control from a distance. For this, the trainer does not have to go to the NPC's position but can take over with the rotary button on the Smart Vest to control the interactions. Using this radial menu, the instructor can select multiple options:

- Open/close doors
- Resurrect or “de-activate” perpetrators and trainees
- Control NPC behaviour (“hands up in the air”, etc.)
- Take over the avatar of an NPC for immediate live role play and let go again of a NPC avatar.
- Show/hide the instructor avatar from the trainees.
- Escalate/de-escalate with use of rotary button
- Create a bookmark in the AAR stream with a quick voice annotation.

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This setup also enables the trainer to use a model-learning approach. For more information on the tasks of a trainer in VR from a didactical perspective, see D7.5, chapter 3.1.8.

Note on Trainer in VR
VR training is not only a digital imitation of a real training, it also enables completely new possibilities for trainers. The trainer can also participate in VR as an observer, but remain invisible to those being trained. He can trigger actions and temporarily take over virtual avatars and act as a role player.

5.2.5 Preparation of Virtual Environments and Scenarios

One of the most important benefits of VR training is the ability to create a wide range of VEs and scenarios within these. The choices for scenarios are essentially limitless, ranging from simulating a domestic violence call to handling an active shooter situation in a school or office building or dealing with agitated and confused mentally ill people in realistic or even 1:1 re-created real-life environments. Ideally LEAs would like to have a large library of environments with different training scenarios to provide trainees with a wide range of training opportunities.

Scenarios require realistic, immersive experiences with correct kinematic movement and ballistics e.g. ability to shoot through windows. Visualisation of indoor as well as outdoor scenarios, during the day and night, and lively urban environments containing a variety of assets like buildings, vehicles and indoor furniture has been identified as an important requirement by the LEAs (see D4.6) and presents one of the most valued advantages of VR in contract to expensive real-life scenario training in re-built training environments on training academies or similar locations. VR training should make use of the big advantage to "train the impossible". A wide range of **avatars** (children, elderly people, physiologically disabled people, all sizes, body-forms, visible origins etc.), **objects** (to create mess and chaos, create different locations like abandoned houses or environments in areas with little socio-economic status) and **environments** (greenery, construction sites, lively city areas), **weather conditions,** etc. should be included to offer scenario variation. Further guidelines for scenario development can be found in D7.7

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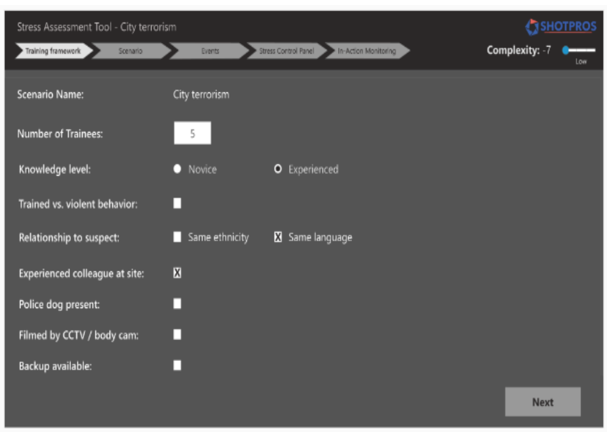
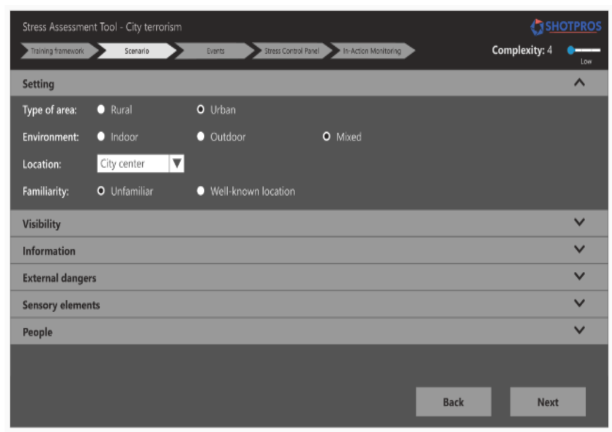
5.2.5.1 Risk Assessment Tool (RAT)

To train in stressful and high-risk situations, VR training developers and trainers need to be able to evaluate elements of scenarios and potential stressors to develop scenarios with the right stress level exposure for trainees. The SHOTPROS project developed a tool to support that process, the so-called Risk Assessment Tool (RAT). The stressors were identified and rated by LEAs as part of the requirements workshops described in D2.2 and evaluated and categorised as part of D4.7.

The screenshots below show screens of a possible implementation of such a tool. Trainers can input information about the team training (group size, experience level) and select their individual requirements for the scenario they wish to create. Current requirements include the **area** they would like to train in (rural, urban, indoor, outdoor), **people** appearing in the scenario (avatars), the **type of assignment** (burglary, terrorist attack, traffic accident), **weapons** (gun, knife) and **additional stressors** (dog, scream). Based on this information, where factors such as years of experience count as stress reducing and factors such as weapons stress increasing, the RAT will calculate a risk/stress score for the training.





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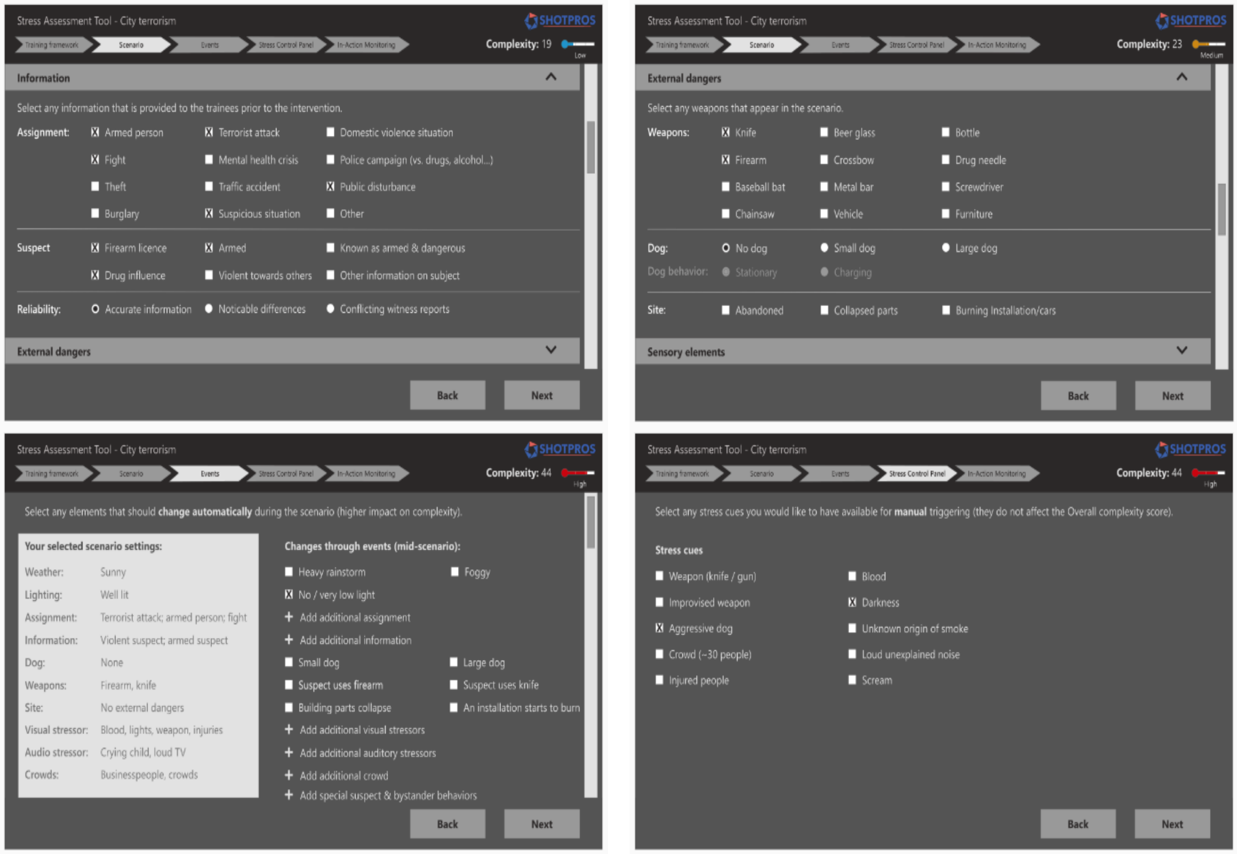

Figure 14: SHOTPROS Risk Assessment Tool to assess stress inducing and reducing elements in a training scenario

5.2.5.2 Scenario Creation – Terrain Editor & Live Editor

Based on identified risks and threats with the risk assessment tool, a fundamental component for creating a realistic environment with realistic training goals is the scenario definition within the scenario editor of the SHOTPROS VR solution. Like in real-world trainings, the trainer must identify and prepare the objectives in advance of the training. To this end, the trainer has to define a clear training assignment, set learning objectives for the VR training sessions and integrate the corresponding elements into the VR scenario (see D7.5, chapter 3.2 Didactical Guidelines for VR Training).

Setting up a new scenario requires several different steps and can be divided into four layers of details in scenario design (see Figure 15). In the SHOTPROS system the creation of the overall virtual

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environment is split into two tools the **Terrain Editor (creating the environment, layer 1 and 2) and the Live Editor (creating the scenario within the environment, layer 3 and 4)**. Starting with the selection or creation of the overall environment (city building(s), open field, streets, re-builds of real-life locations etc.) which is usually provided by the VR platform developer or an external agency as it requires a 3D modelling expert. In the SHOTPROS system this is done in the **Terrain Editor**. The Terrain Editor is used to model the terrain, streets, create buildings, windows and doors, and place 3D objects to make the environment lively. With the Live Editor, the details in the buildings and rooms are enriched, NPCs are added and the behaviour specified as well as surprise moments are set with trigger zones (also see D7.7 scenario guidelines for DMA-SR). Typically, the Live Editor can be used by a trained end user as well (see D8.5, Policy-maker toolkit – the introduction to internal processes).

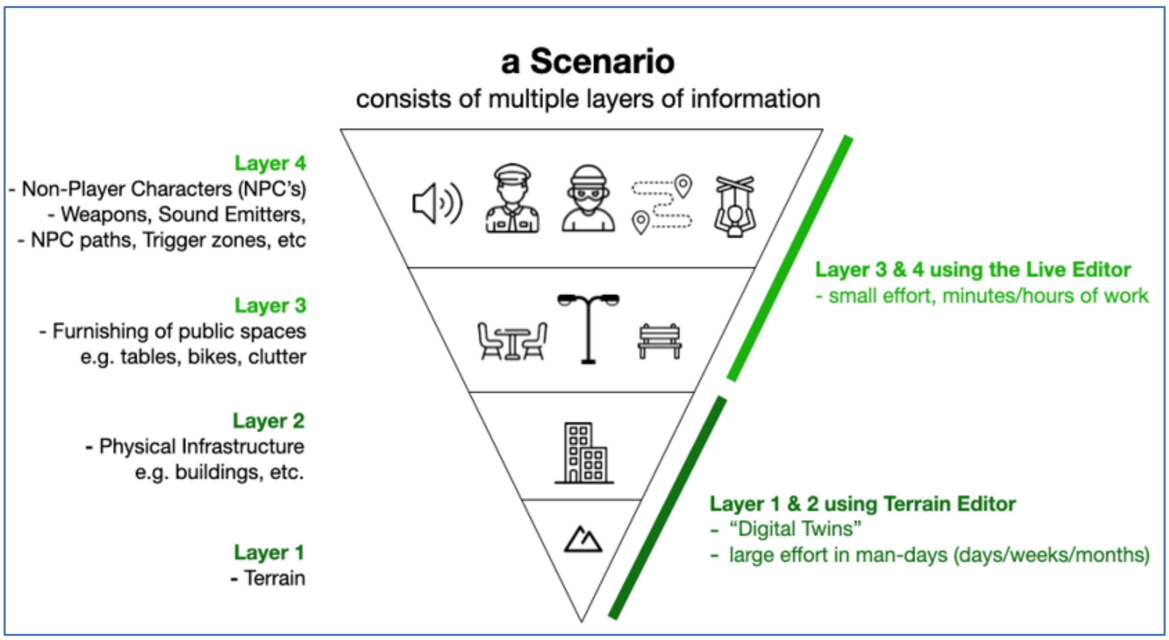

Figure 15: The 4 layers of good scenario design and the relevant tools for it

Terrain Editor

LEAs often want to train in a specific environment that realistically resembles a building or area in their local area (e.g. a train station, government building or streets). In the SHOTPROS VR solution, this can be done in the Terrain Editor but needs more training than the usage of the Live Editor. In the Terrain Editor a place can be chosen from a map and additional geo data about elevation or

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imagery can be imported for this place. Buildings can be constructed by drawing walls, windows and doors over an imported building ground plan.

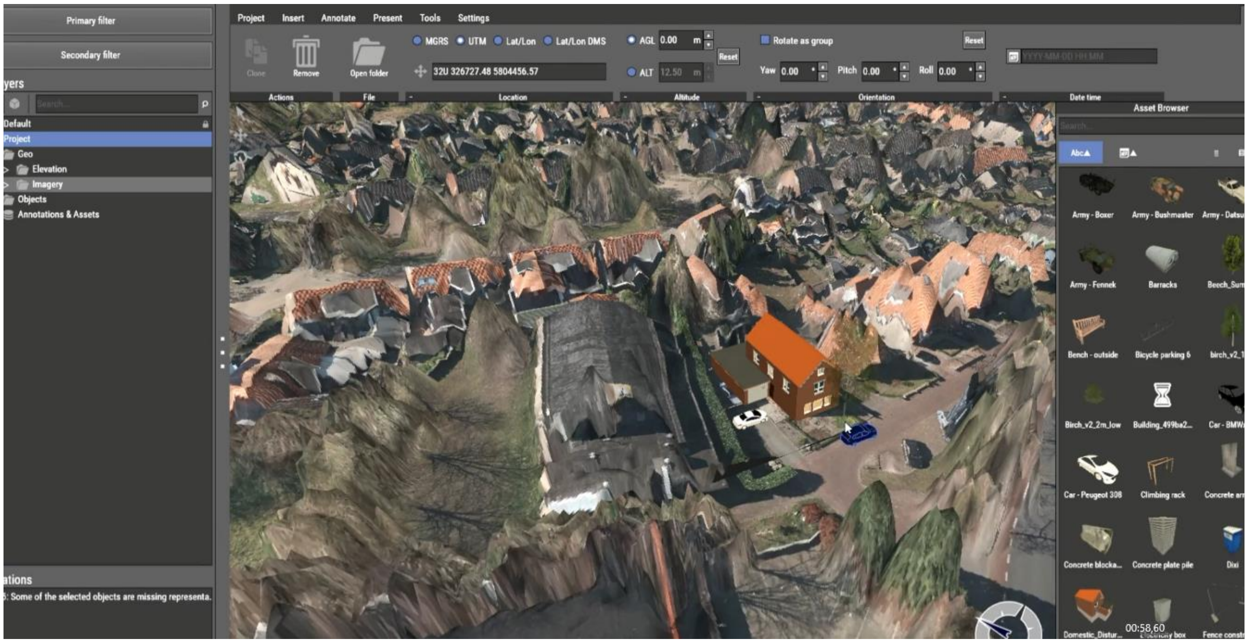

Figure 16: Terrain Editor to create a lifelike setting with streets, buildings and cars based on a real environment.

It is however convenient if virtual environments can be customised with minor changes (different furniture, avatar clothing, weapons, animations) without necessarily involving a specialist 3D/VR developer. Therefore, within the SHOTPROS VR solution, these adjustments can be done in **the Live Editor** for scenario creation.

Live Editor

To have the ability to create a variety of scenarios, a substantial selection of objects (e.g. furniture, cars, weapons, smoke, weather conditions, etc) and avatars (including a variety of ethnicities, styles and clothes) should be available. Finally, animations, walking paths and behaviour pre-sets need to be defined as well as triggers which start a certain automated action. Although it is possible to give trainers the opportunity to trigger such actions manually through the Live Editor (e.g. a dog entering the room, noise of gun shots) the SHOTPROS end-user studies showed a demand towards automatisation. It was important for trainers to pre-define decision-points and create a flow that

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depends on actions of a trainee and not on a certain point in time. To achieve this, the SHOTPROS VR solution offers to pre-define certain trigger zones for specific actions. For example, when a trainee enters the room (i.e. crosses a trigger zone, pre-located to a certain spot where the trainees “should” cross according to the training objectives), shots are audible or when the trainee comes closer to a certain NPC and crosses the pre-defined, but for the trainee not visible trigger zone, another NPC starts to scream, or another gunshot is audible from another room etc.

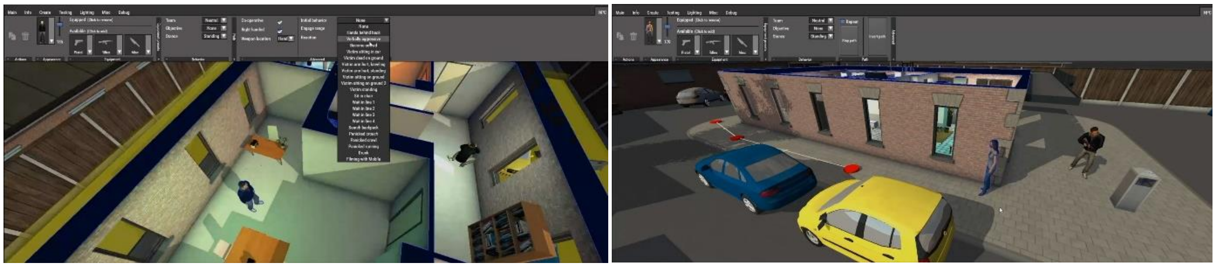

Figure 17: SHOTPROS Scenario Editor

As soon as the scenario is designed according to the training objectives, it can still be adapted live during the execution of the training – the Live Editor gives trainers and operators then the opportunity to interfere and steer the training while it is on-going (e.g. manually trigger a pre-defined behaviour of an NPC or add/remove certain objects from the scenario), to provide individualised and customised training. Examples include escalation of a situation through triggering of virtual stressors (e.g. a crying child at a crime scene) or reaction of an NPC with or without voice action. Intervening live in the action offers a lot of freedom to adapt the original specifications on-the-fly as needed. This requires a well-designed user interface that allows for live interactions and also feedback when an adjustment is necessary. This is typically done by an operator in close communication with the trainer so that the trainer can focus on the didactical aspects (see D7.5) nevertheless, a trainer can be trained on the usage of the Live Editor and this task can be done by a member of the LEA organisation as well, caused by the high usability focus of the tool.

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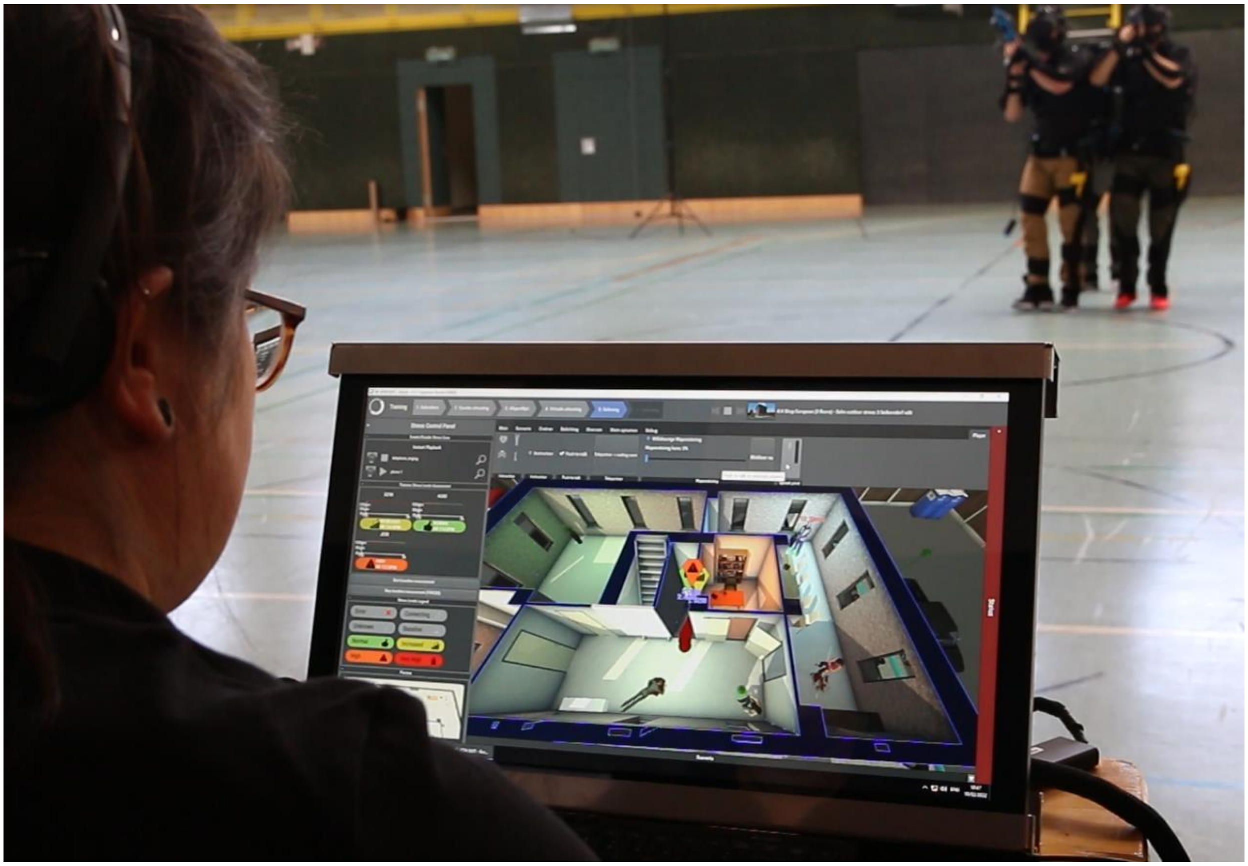

Figure 18: SHOTPROS Live Scenario Editor at operator station

In the SHOTPROS VR solution, the Terrain Editor and Live Editor are separated mainly for technical system performance reasons but also to divide expert tasks (Terrain Editor) from tasks that can be executed by trained users as well (Live Editor). The Terrain Editor is highly optimised for fast loading and use in VR, and can be considered as static data. Objects and actions added through the Live Editor can be manipulated throughout the scenario and therefore have to stay "live".

Note on Preparation of Virtual Environments and Scenarios
As with real-life training, VR training means designing suitable environments based on the training objectives and bringing them to life with the relevant content and action. Depending on the course of the training, challenges and stressors should be increased or reduced. What seems almost impossible in real-life training with the coordination of several role players can, in contrast, be controlled more easily in VR with storylines for several virtual avatars. It is

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important to have the appropriate tools available that support fast, simple creation and live adaptation. In SHOTPROS, this task is divided into two tools, the Terrain Editor and the Live Editor.

5.2.6 Performance Monitoring In-Action and After-Action Review

5.2.6.1 In-Action Monitoring (IAM) - real-time

Effective DMA-SR training not only provides feedback at the end of a training sessions (typically known as debriefing) but also integrates feedback throughout the training session (see D7.5). In-action monitoring is the ability to live-view the training scenario with a real-time update on pre-defined key performance indicators (KPIs) and the trainer's didactical view. A list of 12 highest-rated KPIs for In-Action Monitoring by police trainers is available in the appendix of this document.

An example of what this could look like including most important elements highlighted, you can find below in the Figure 19 from the current SHOTPROS VR solution.

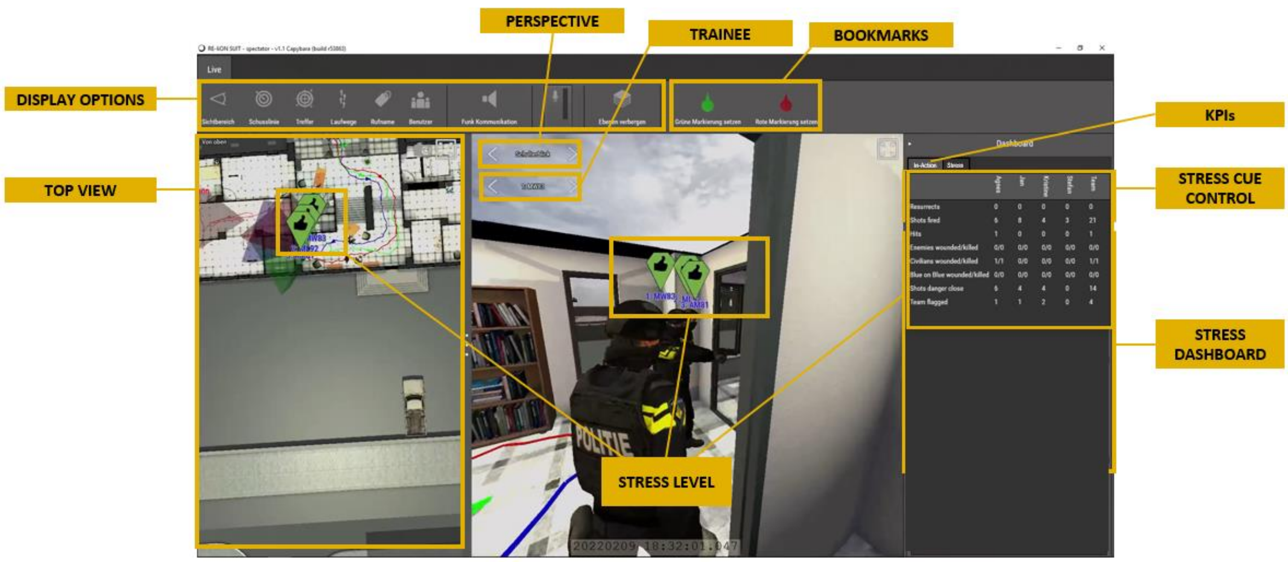

Figure 19: SHOTPROS In-Action Monitoring incl. its most important features

In real-life scenario training, monitoring performance indicators in real-time can be a challenge for trainers. Police officers usually train in groups of 3-4 which makes it almost impossible for trainers

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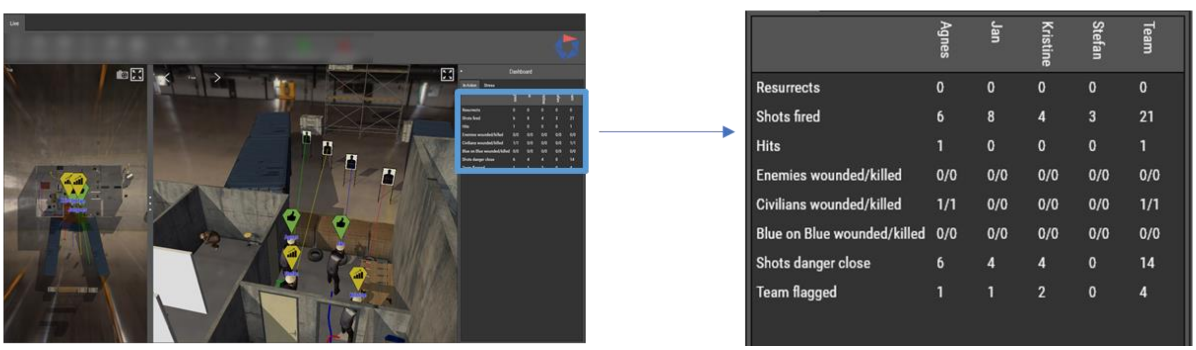
to monitor, for example the field of vision, of all trainees at the same time or losses the direct impact if for example 4 camera recordings need to be analysed before being able to give feedback.

Based on requirements collected from the LEAs (see D4.6), feedback from EndUser FeedbackWeeks (in Berlin and Selm) and other conducted HF studies (see D6.1), the following objectives were defined for an In-Action Monitoring:

- Measure and track training progress of trainee(s) in real-time (stress, performance), shown in Figure 20.
  - current stress level based on physiological measurements (see chapter 5.2.7) and
  - performance of trainee based on pre-defined KPIs (see above)
- Enhance training performance and related outcomes by giving trainers the opportunity to dynamically introduce psychological (e.g. anxiety inducing) and physiological cues (e.g. audio stressors such as loud music) to practice Decision Making and Acting (DMA) in stressful situations (see D7.4).
- Help trainers and spectators to understand the relationship between stress- and anxiety-inducing factors and their impact on the DMA process.



	Agnes	Jan	Kristine	Stefan	Team
Resurrects	0	0	0	0	0
Shots fired	6	8	4	3	21
Hits	1	0	0	0	1
Enemies wounded/killed	0/0	0/0	0/0	0/0	0/0
Civilians wounded/killed	1/1	0/0	0/0	0/0	1/1
Blue on Blue wounded/killed	0/0	0/0	0/0	0/0	0/0
Shots danger close	6	4	4	0	14
Team flagged	1	1	2	0	4

Figure 20: In-Action Monitoring showing the selected KPIs per trainee and as team

In the SHOTPROS VR solution, the *In-Action Monitoring* can be expanded horizontally as a panel, to not lose the entire screen and live action view. The KPIs displayed (individually and on group level where suitable) need to be selected during the scenario set up process (example screenshot below Figure 21). More detailed information on In-Action Monitoring can be found in D4.5.

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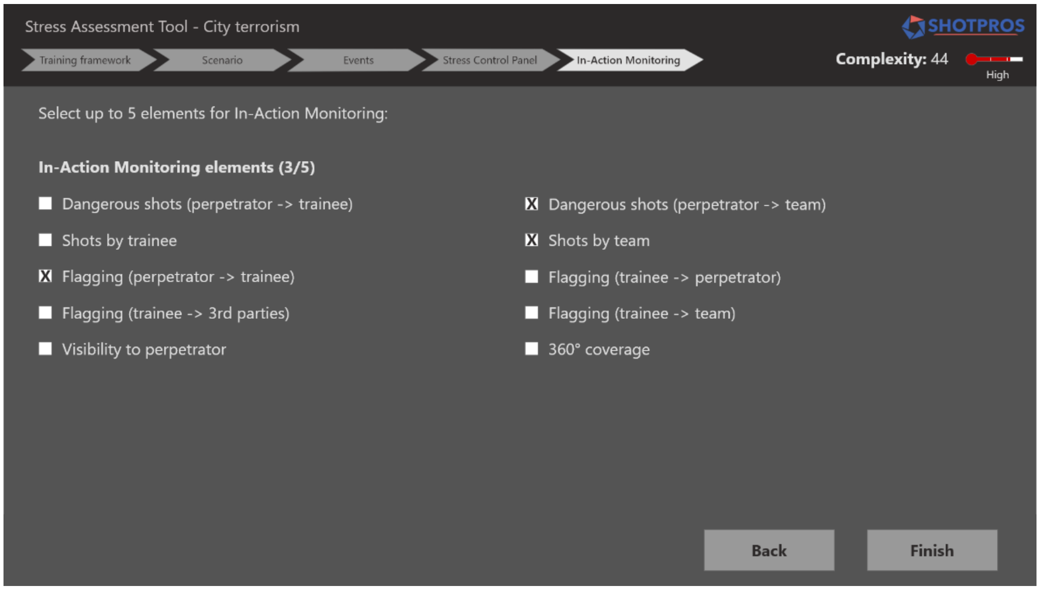

Figure 21: Mock-up of In-Action Monitoring KPI selection process in the RAT

5.2.6.2 After Action Review (AAR) – debriefing the training

The AAR has been rated as one of the biggest advantages of VR training by our participating LEAs. In real-world training measuring objective performance can be a challenge and often requires setting up multiple cameras and long manual analysis afterwards if it is possible at all. The fact that the entire training is recorded in VR and can be replayed and viewed from multiple angles at any point in the scenario has been a highly appreciated feature throughout all the field trials and has been identified as a major opportunity and advantage of VR training.

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Figure 22: AAR at the trainer station (touch screen for the trainer and big screen for viewers)

The primary benefit of VR is the ability to record every movement and environment change. In contrast to traditional video recordings, the 3D environment in VR records all learners' positions along with their foot, hand, and head motions as well as all actual and simulated items that are used during the training session. This opens up the opportunity of changing and freely choosing the perspective for reviewing the training session as needed in the AAR.

Another benefit is also the automated logging of events (door opening, gun fired, etc.) which can be quickly accessed via the timeline. For performance measurement, there are also KPIs that can be processed automatically, such as shots fired, hits, enemies wounded or killed, civilians wounded or killed or shots danger close to name a few. The current SHOTPROS solution includes the following KPIs:

- Physical positions, motion and pose of trainees and NPCs
- Trainee walking paths

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- Line of sight
- Field of view
- Firing events
- Firing lines
- Impacts
- Radio chatter and other sound

Figure 23: Example screen of the graphical user interface for AAR.

Events are automatically bookmarked by the system and can be added manually to efficiently navigate through the debriefing process and focus on important decision-making points. SHOTPROS large touchscreen and game-controller to navigate have been rated very positive throughout the project.

In addition to KPIs physiological data, indicating stress levels are recorded and displayed in the AAR as described in the next chapter as well as in more detail in D4.5 and 5.4.

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Each behaviour can be examined in relation to the environment and the trainee's degree of stress, allowing the causes of a behaviour to be more precisely pinpointed (signs of avoidance behaviour, freezing, and hesitation), and the aspects that need to be addressed to be more specifically trained.

AAR offers great possibility to store valuable training information to monitor progress and performance over time. However, anonymity of data, short vs. long-term storage, accessibility, visibility of individual data to others needs to be considered by policymakers and LEA representatives for a successful implementation (see chapter 5.5). Further details on AAR can be found in D5.4 and best practice with the After-Action Review for self-regulation of learning per VR training phase can be found in D7.5.

Note on Performance Monitoring In-Action and After-Action Review
Performance monitoring is an innovative element of VR Training. In real training sessions with several trainees, it is hard to capture objective performance evaluations live. In VR, every movement and all performance outcomes are recorded. With the live evaluation, the basis for the live adaptation of the training to the needs of the trainees is created. With the Live Stress Assessment, SHOTPROS offers an innovation that closes this feedback loop to the trainee and makes the need for adaptation and also the reactions to changes clearly visible. In the after-action review, all movements, tactics and behaviours can be tracked and evaluated. Sections can be directly selected, paused or repeated, the perspective can be changed and evidence-based feedback supported by stress measurement and KPIs can be given.

5.2.7 Stress Dashboard based on Biosignal Measurements

VR training is especially useful for training DMA-SR training of police officers. Having a VR system that helps to understand and monitor the trainee's physiological state, indicating stress, is a crucial part of such a system (see D7.4)

5.2.7.1 Biosignal Measurement and Wearable Devices

Through several human factor studies and field trials the SHOTPROS project has identified HRV in combination with HR to be a good indicator of real-time stress levels. To measure these biosignals the Zephyr™ BioHarness™ (chest strap) had been used. Throughout the FTs the cheststrap has proven itself as a reliable sensor that is relatively easy to put on and comfortable to wear during the training.

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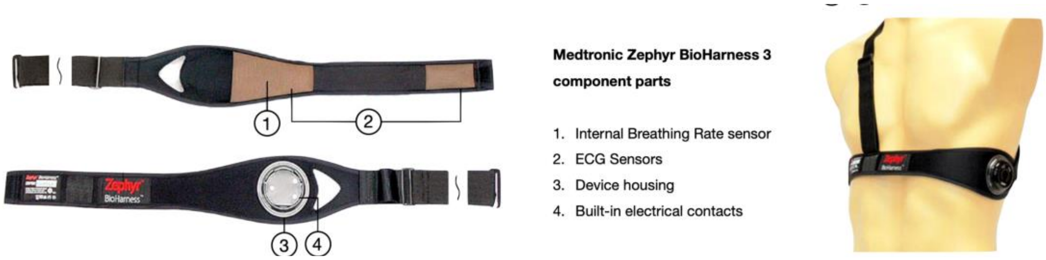

Figure 24: Zephyr™ BioHarness™ 3.0 (property of Zephyr Technology Corporation, Annapolis, MD, USA—a division of Medtronic).

For the stress indicator to work, an individual baseline (2 minutes) needs to be recorded before the training. In the SHOTPROS system this has been built into the VR system.

5.2.7.2 Stress Level Assessment Dashboard

During the training, 30 seconds intervals moving averages of HR and HRV (based on the RMSSD method) are compared to the trainee's individual baseline and weighted according to our stress model (see D4.5). The resulting value is classified into one of four categories: 1) normal, 2) increased, 3) high and 4) very high. If no values are available due technical issues, this is indicated in grey colour and a red cross).

Figure 25: Stress Level Indicator during Training

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5.2.7.3 Stress Control Panel

The *Stress Cue Control* panel (Figure 26) gives trainers the possibility to add stress cues, either ad-hoc with instant playback or time-controlled via a time axis. If the user presses the play button, the stress cue is activated in the VR scenario as concrete, observable audio and/or visual stimuli (e.g. a dog starts barking).

Figure 26: Stress cue control panel to add stress cues.

The end user requirements (D2.2) and EndUser FeedbackWeeks (D6.1) indicated that an efficient, effective interaction and an easy-to-use user interface design is needed for this feature. It allows for observations of the training and trainees' behaviour and adaptations to the scenario by (de)activating stress cues rapidly with little mental effort for the user. With the similarity of the buttons to an audio/video player a very common and easy to understand visual element was used that meets the user-based requirements.

For VR training, especially DMA-SR training, it is important to be able to increase the level of complexity of a baseline scenario by adding augmentations and stressors. A content pool of a variety of assets and animations should be available to choose from. For SHOTPROS, a relevant pool of assets has been described in WP4.

The following stressors were identified by partner LEAs:

Assets / Augmentations	Description
Aggressive dog	Dog barks and runs at user

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Being filmed	Unknown person stands inside a closed room and points a camera at the user
blood	In room are traces of blood
bullets	In room are bullets spread on the ground
Child crying	Child sits in room (e.g. crying)
Cluelessness	User is not given any information
Collapsing building or building parts	as threat to physical integrity
Crazy and unresponsive behaviour	Unknown person sits in room and laughs uncontrollably
Crowd (approx. 30 people)	Trainee stands in front of a crowd of people (multiple crowd behaviours possible)
Darkness	Closed room (or street) with no or very little light
Filmed by bystanders	Unknown person stands outside and points a camera at the user
Getting asked by bystanders	Unknown person approaches user and bombards him with question without waiting for answers
Loss of communication to colleague	Sudden loss of communication to colleague that entered flat / street with the trainee together
Loud unexplained noise	Door is banged shut after user walked inside the room / In closed room TV is running and producing loud sudden sounds.
Not understanding person talking to you	Unknown person sits in room and talks to user, but in unknown language
Person just starring at you	Unknown person sits in room and does not say anything
Possibly aggressive dog	Dog is stationary but barks at user
Scream	Scream audible while inside a closed room
Unexpected person	Unknown person walks into room from behind
Unexpected silence	After the police officers opens the door there's no noise at all, even after asking for a response from expected inhabitants there is nothing to hear.
Unexpected weapons	Unknown person stands in the room and uses ashtray, vase as weapon
Unknown origin of smoke	Closed room gets filled with smoke.
Unresponsive person	Unknown person sits in room and is unresponsive / Unknown person sits in room and laughs uncontrollably
Visual overload	Room is full of objects (e.g. furniture)
Weapon (knife/gun)	Trainee looks into a room and sees a knife / gun and a hand holding it
Fog	Weather is foggy
Limited visibility	In hall with several doors and light starts flickering.

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Weather	Weather is bad and it rains
Odour / Smell	User opens trunk and body odour comes out of it
Gas smell	Closed room smells of gas

Table 7: Pool of assets identified by LEAs in WP4

In the current version of the SHOTPROS system, trainers are only able to activate or deactivate stress cues via the Trainer Dashboard at the trainer station (Figure 26). Feedback from the Field Trials showed a preference to be more flexible and potentially able to steer the training from the training field. Therefore, considerations about future interaction devices such as tablets or smart devices should be made.

Scientific backup

The twelve most relevant stress cues have been evaluated in the Human Factor Study: Berlin Stress with the aim to quantify and rank each stressor (for more details about the study see D7.1 chapter 3.11 and D4.5 ANNEX 1).

Both subjective (visual analogue scale for stress and anxiety) and physiological responses (heart rate and heart rate variability) have been measured and analysed with the following outcome:

	Subjective Measurements							**Physiological Reactivity to Baseline**						
	Stress				**Anxiety**			**change in HR**				**change in HRV**		
Stressor	n	mean	SD	Rank	mean	SD	Rank	n	mean	SD	Rank	mean	SD	Rank
Dog	22	17.18	12.73	11	11.86	9.71	9	14	8.69	13.30	8	-13.65	20.43	3
Weapon	22	38.18	19.27	2	26.23	16.71	2	14	9.20	14.79	4	-6.57	14.12	10
Injured	22	27.91	18.72	4	17.95	11.25	4	14	13.53	16.06	1	-14.01	21.32	2
Photo (Day)	22	16.59	15.94	12	5.68	5.40	13	14	-0.51	22.03	9	-1.29	38.00	11
Photo (Night)	22	14.73	15.56	13	5.95	5.64	12	14	-2.16	22.97	10	-12.81	35.32	5
FallingRocks	19	32.32	22.06	3	18.05	15.11	3	9	-4.46	27.06	11	-7.20	30.21	9
DoorClosing	22	24.05	22.58	7	17.14	21.17	5	15	10.13	23.34	3	-12.97	37.50	4
CryingChild	22	27.41	23.88	5	13.00	20.09	7	15	8.98	23.02	6	-9.42	32.04	6
Smoke	22	23.09	18.52	8	11.82	13.04	10	15	8.86	23.61	7	-8.51	35.83	7
DarkRoom	22	19.45	20.69	9	12.59	14.55	8	14	11.74	23.79	2	-8.27	29.83	8
Stranger	22	41.45	26.24	1	28.41	23.94	1	12	8.99	23.00	5	-15.08	22.49	1

Figure 27: Subjective and physiological measurement results for individual stress cues.

The results show a clear physiological response to stressors. Although this response, as well as baseline values, shows great heterogeneity when comparing individuals and individual stress cues, at the group level we can see a clear trend. Average HR increased compared to the baseline amongst

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all participants for all stress cues except "falling rocks", which could be due to data issues created by movement artifacts. Many participants jumped aside when the rocks fell on the floor in front of them, creating a strong, sudden movement that effected data quality and the removal of several data points. Average HRV decreased compared to the baseline for all stress cues (see figures below)

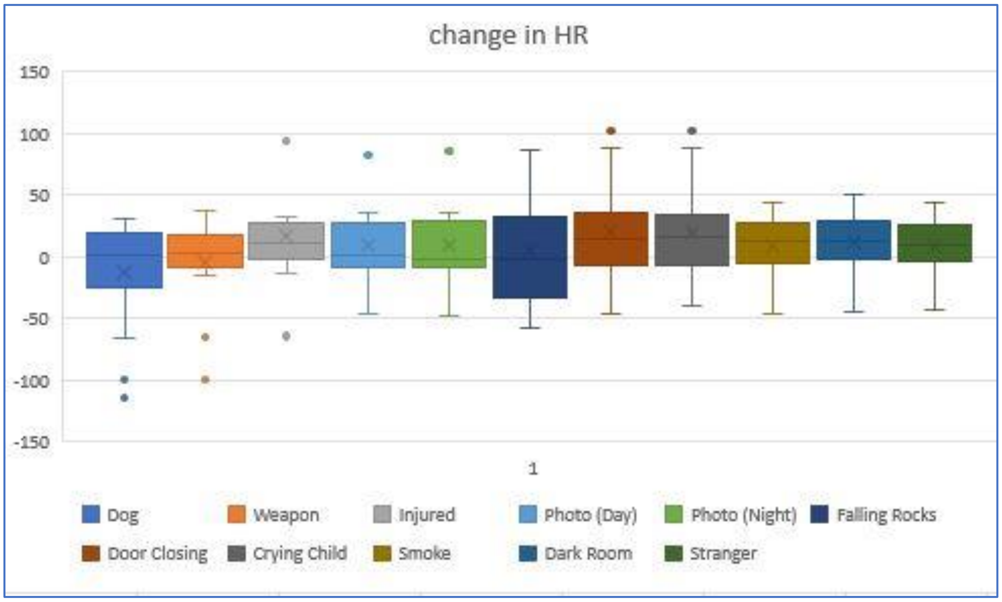

Figure 28: Change in HR relative to baseline for all stress cues.

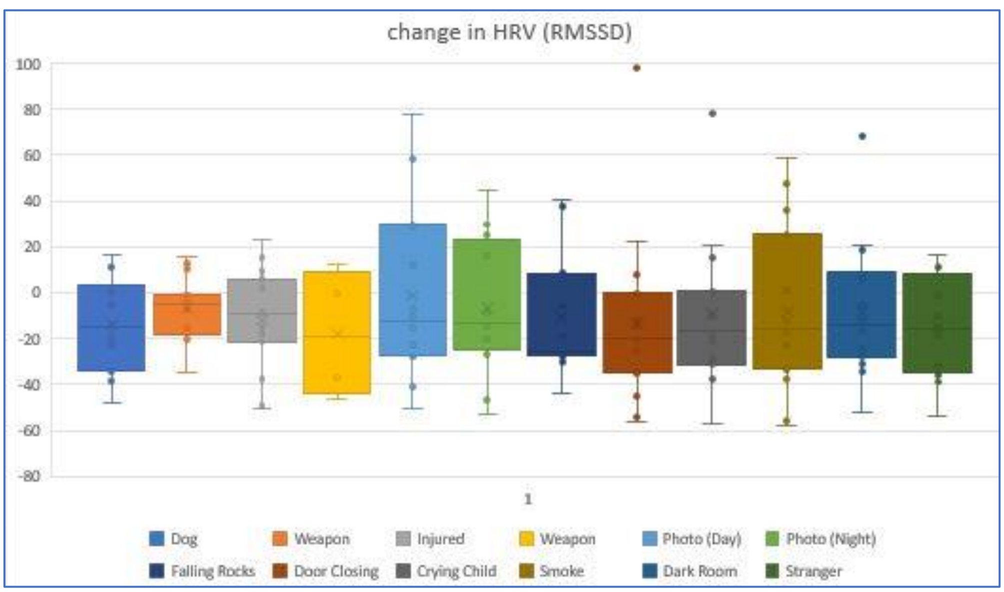

Figure 29: Change in HRV relative to baseline for all stress cues.

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Note on Stress Dashboard based on Biosignal Measurements
The stress assessment and visualisation on a dashboard helps to monitor and understand trainee's state. The stress assessment is based on biosignal measurements and the ranges vary greatly between individuals. A baseline measurement must therefore be taken at the start of the training. In the baseline measurement, the initial state is measured. However, if the trainee is already in an increased state of stress or suffers from chronic stress, a false baseline is measured. As a result, increases in the stress state are hardly achieved and further stressors are relentlessly activated in the scenario, which can lead to overload. This is where the trainer plays an important role in preventing such a situation.

5.3 Guidelines on Resources

5.3.1 Training Facility Requirements Considerations

Free movement is an important feature in simulation training. Although several alternative movement options exist in VR (see chapter 5.1.5) feedback from LEAs suggested a strong preference towards natural movement options, which requires a lot more space than other options. These natural movements are also a must for DMA-SR training. The space needs to be empty and requires a **solid floor**. Soft carpets or slippery materials could cause the trainee to fall over and injure themselves. Disruptive **cabling** also needs to be considered and should be routed around the edges of the training field. For a functional and safe space to manoeuvre, the training pitch needs to be free of any obstacles or clutter. Depending on the tracking mechanism used (see chapter 5.1.2) the room needs to have a certain height and have **clear line of sight**, to ensure trainees are in view (and can be tracked) wherever they go. Furthermore, items that can interfere with **light**, such as reflective surfaces (windows, glass, etc.), direct sunlight and infrared light sources (if the system uses infrared motion tracking) need to be considered.

In addition to the actual training field, it also needs to be considered that the following elements require additional space:

- Equipment storage area
- Operator station
- Trainer station
- After action review

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For example, the SHOTPROS full body system provides the opportunity to train on an area up to 100 x 70 meters with a typical space used in gym halls of 30 x 30 meters obstacle free space.

The training set-up as presented in the graphic below has been evaluated in five separate field trials. Feedback provided by trainees and trainers highlighted the following points as important:

A **separate change room** where trainees can also leave their spare clothes and belongings. During the field trials we have tested putting a monitor with a short introductory video into the change room or waiting area, which received a lot of positive feedback and was considered very helpful when putting on the suits, headset and explaining the training procedure.

The **operator and trainer stations** need to be kept **close to training pitch** in order to see trainees. The AAR station has been tested close to the training pitch as well as in a separate room. Having it on the training field it has the advantage that regular reviews can be done throughout the training as needed. Having it in a separate room has the advantage that a new group of trainees can already start a training session while the other group is conducting the AAR. There was no clear recommendation from LEAs. It is therefore important to be clear about training goals, group sizes and timings as well as and potential rotations before setting up the training field.

The **training pitch** itself should be a **quiet area** that does not expose trainees to noise or other distractions, which would interfere with the level of immersion trainees should experience throughout the training.

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Figure 30: Schematic presentation of recommended training area

In comparison the compact version of the SHOTPROS system, which has also been tested at the field trials, requires a lot less space (approx. 6 by 6 meters). But this comes with restrictions. If natural movement is required, the scenario needs to be small enough to fit into the space provided or alternative movement options need to be used. Being clear about training goals and what kind of scenarios organisations want to train will help making a decision on physical space requirements of the VR system.

5.3.2 Human Resources Requirements

In order to operate a successful scenario-based DMA VR training, several people are needed to operate the system and lead the training. For the training execution at least, the following positions need to be filled:

- Operator
- Trainer
- Role player (which could be the trainer)

For more detailed descriptions of the roles please refer to D7.5, chapter 3.1.2.

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Trainee group sizes depend on the availability of Smart Vests or tracking devices and the computational power needed to track these devices. Ideally the number of trainees in VR should correspond with the number of the real-life duty on patrol. Additional trainees can be used as role-players.

Depending on the VR system, resources for set-up, technical infrastructure and scenario development/adaptations need to be considered.

The advantage of a stationary training set-up is that the set-up, including IT infrastructure, only needs to happen once. The SHOTPROS system also offers the advantage of relatively easy scenario adaptation, which can be done in-house by the trainer. However, not all VR systems on the market offer such solutions and this should be considered when comparing different options.

5.3.3 Procedure and Duration of a Training Session

A typical VR training session includes the following activities:

- Preparation (putting gear on, calibrating, VR tutorial, material check)
- Instruction (instruction of exercise, role-player and officer, tutorial scenario)
- Execution (actively engaged in a training scenario as a role-player or officer)
- Feedback (from the trainer, from other trainees, self-reflection, AAR).
- Waiting (trainer is busy, operator is busy, social time)

The duration of a high-quality and effective VR training session should be a minimum of 1.5 hours to ensure sufficient training of DMA-SR behaviours and allow for sufficient execution time in VR. To make extensive use of the VR after action review (AAR) tool, the duration of a VR session should be extended for AAR to a minimum of 2 hours. For further information and recommendations on training curriculum and didactical guidelines please refer to D7.5, chapter 3.1.4.

Depending on the system, time for dressing up, calibration and tutorials needs to be allocated. This can take between 15 and 40 minutes. It should also be considered that trainees who are unfamiliar with VR may need longer to get used to the VE and will need to be allocated some extra time for tutorials.

5.3.4 Training Set up and Preparation

Planning and preparation for a training should start several weeks before the actual implementation of the training. The actual time frame very much depends on the novelty factor of the training and

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availability of developers. If entirely new terrains and scenarios are needed, we recommend discussing this with the VR provider well in advance.

The preparations for setting up the training system depend, of course, on whether a system is permanently installed or only rented and temporarily set up for training. With a permanent installation no additional preparations for the VR training itself are needed and the trainees travels there to train. If the product is a “train-as-a-service” solution, the need for transportability of the training equipment becomes more important as the training provider needs to save time and money in transportation and set-up to be reasonable and to train as many people as possible in one working day. The travelling of trainees to a centralised training location also induces the need for training solutions that can be provided in a high number of police stations to make use of the time between operation as or when training locations are not available.

Once the **training goals** are established, appropriate **virtual environments (terrains)** need to be selected or built. Depending on the complexity of these terrains and availability of resources with developers this can take anywhere between a few hours to weeks. We recommend creating a service level agreement with the VR developer to ensure both parties have a fair understanding of development timings should new assets and terrains be required.

One or several **storylines** need to be scripted to involve trainees in the desired activities and behaviour within a scenario. For scenarios to look realistic virtual environments need to be “dressed up” with **furniture, lighting, props, weather and avatars** (including clothing, equipment and behaviour). Avatars need to be given certain tasks or behaviour often involving the setting up of **trigger zones**, to start a certain action.

Stress cues should be either built-into the scenario already or set-up for trainers to be used on the spot if that feature is available in the VR training platform.

Physical props and **tactical belt** should be considered when developing a scenario. If trainees are required to use a pepper spray or stun gun for example, it needs to be made sure that these props are available and that trainees know how to use them (either through previous experience or a tutorial before the training).

If the training includes one or more **role players**, they need to be given a briefing or script on what to do and how to respond to trainees.

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For police officers scenarios often start with **radio communication** and a task from the police-station. Consider how these can be given in a consistent way (e.g. either pre-recorded or via the operator).

For guidelines and recommendations on the training curriculum please refer to D7.5.

5.4 IT and Data Security Guidelines

Data security is very relevant in public organisations, such as LEAs. For security reasons and system stability it is important that the VR training system setup uses an own networking equipment and is not connected to the LEA network environment. Another important aspect is data security for recorded data: all data generated (scenarios and AARs) are stored on a solid-state drive in the VR system. This ensures containment and makes it easy from an administrative point of view to archive or remove data when needed. For the future it is requested by LEAs that trainee data (such as name, height etc.) can be stored in profiles and loaded to save time in the set-up phase and also to have a progress of the performance data over time and probably build reports on that. But the allowance for such a storage will be different from state to state, therefore this needs to be compliant with the relevant public organisation and national law.

5.5 Ethics Guidelines

When developing or using a certain VR system, it is imperative that one should also reflect on certain issues from an ethical perspective. Throughout the SHOTPROS project, it has become clear that people do have certain concerns about ethical aspects related to police training in VR. When highlighting certain ethical considerations to LEA management, trainers and practitioners, it often makes them aware that the decision to train in VR should not be taken lightly. Often, people are a bit 'bedazzled' by the technological possibilities in VR and the new potential it brings to police training, that they forget the possible dangers and new challenges that it might bring up. There are no strict recommendations as to how to solve such ethical problems, only guidelines concerning how to put them forward as a subject for discussion.

In terms of ethical considerations, we will focus on three main aspects in this deliverable: (a) protection of user data, (b) well-being of trainees, and (c) ethics in VR scenario design. For more details on that, see D8.5, policy-maker toolkit.

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5.6 Potential Challenges in VR Training

VR training is proven to have benefits for DMA-SR training, but like any other training type or any other technology, it also brings challenges to the trainers and trainees that need to be considered before setting-up a VR training

5.6.1 Calibration

One of the main challenges of VR training is the correct calibration of the user's positions and extremities. This refers to the preciseness and timeliness of tracking the various tracking points on the user's body. Specifically, problems in calibration lead to the users' virtual arms or legs being in the wrong angle or position or to delayed movements of the virtual avatar, which in turn can lead to a break in immersion. When users are pulled out of the experience by such technical challenges, the training loses its naturalness, and focus shifts from the training goal or task at hand to dealing with these technical disturbances.

Within the SHOTPROS system, calibration was identified as one of the main challenges. As the VR system uses radio signals to triangulate the position of the trackers on the users' bodies, it requires to reserve some time before the start of the training for calibration. In this time, users walk in predefined patterns and calibrate the right alignment of their prop gun, hands and feet. From the user experience studies described in chapter 6 we gathered, that for many participants the calibration process and accuracy could be improved upon. For one, the calibration phase took longer than users would have wished, but also some reported issues with the perception and estimation of distances. A few users also reported a delay of their movements in the virtual environment which reduced the immersion of the training.

Calibration accuracy, but also the length of the calibration process is an important factor when choosing a VR system for police training. An ideal system would feature a quick calibration process with good accuracy and little latency throughout the training. This enables a smoother overall procedure, with more groups being able to train.

5.6.2 Motion Sickness

There are three general categories of causes for motion sickness:

- Motion which is felt (sensed) but cannot be seen (e.g. sea, air, or car sickness)

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- Visually-induced motion sickness, such as cybersickness, where motion is seen but not felt (e.g. riding a virtual rollercoaster while sitting on a chair)
- Disagreement between the visual and vestibular systems on detection of motion.

Cybersickness is a form of motion sickness that occurs when immersed in a computer generated environment such as VR. When motion portrayed in the viewport is detected by our visual system but not match by our vestibular sense, cybersickness symptoms can occur. Symptoms can include: dizziness, lack of coordination, disorientation, oculomotor discomfort, headaches and nausea.

In general, there are three types of contributing factors:
1. System factors: introduced by the hardware and operating system (e.g. lag and pixelation).
2. Application and User Interaction factors: caused by the design of the software, the user experience, and how the user chooses to interact (e.g. mode of locomotion).
3. Individual (e.g. some get car sickness others don't)

Some suggestions that can help with cybersickness:

- Try to use natural movement as mode of locomotion when possible.
- Place virtual objects at a comfortable viewing distance.
- Avoid repeating patterns and high spatial frequency contents (e.g. stripes or fine textures).
- Give new users enough time to adjust to the virtual environments before starting a real training. For example: in the compact version of the SHOTPROS system a play room has been introduced where trainees can interact with objects in a fun and playful manner.
- Avoid including elements that induce vertical acceleration (e.g. stairs). Although **stairs** are part of real-life situations and would enhance the range of environments, it became clear during the SHOTPROS project that stairs should be avoided in scenarios as they enhance the likeliness of motion sickness and decrease the level of immersion.

Although motion sickness was a much talked about topic in the beginning of the project. In the feedback collected during the field trials the topic was not mentioned at all.

5.6.3 NPCs Reaction and Communication

The number of NPCs in given scenario poses a challenge with current technology in terms of computing power. As NPCs need to be responsive and controllable to allow for a dynamic interaction, this adds a lot of computational load. With rising computing power, the impact of this

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challenge will be lessened in the coming years, but at the moment needs to be considered when planning training scenarios involving NPCs.

When talking about the responsiveness and naturalness of NPC interaction, it has also to be mentioned that this poses a challenge as well. Especially face-to-face interaction with NPCs is still at an early stage in VR training solutions. Social cues like facial expressions corresponding to the contents of an interaction are crucial for social realism. At the moment this is difficult to realize, as social interactions are complex and would take a lot of computing power and enabling by AI recognizing content and emotionality of speech interactions to simulate automatically. It is possible however, to have scripted interactions, where NPCs have a certain dialog that can be changed by the trainer depending on the trainee's interaction.

In the SHOTPROS system, around 10-15 NPCs can be included in a given scenario, depending on the complexity of the virtual environment in which the scenario is set and the number of trainees / role-players in the scenario. The interaction with NPCs in the SHOTPROS system was partly an unfamiliar situation for the trainees, as their responsiveness is still a basic level.

5.6.4 Interactions

Interacting with the virtual environment or other trainees in the scenario still poses some challenges with current technology. For one, to be able to use non-verbal forms of communication, like touching team-members at the shoulder, the precision of tracking needs to be improved even further. When a person is expected at a certain location because their avatar is perceived there, the person should actually be in that exact location. Feedback during the Field Trials of the SHOTPROS project revealed, that from time to time it happened that trainees grabbed into space when expecting their team-member, which led to uncertainty and a reduction of immersion. This issue also exists with other tracking technologies and needs to be improved upon in the future to guarantee a more realistic haptic and social training experience.

Also summarized under the term "interaction" are challenges in the interaction with virtual objects. Though already integrated in the newer compact version, the latest version of the Full-Body version does not offer physics simulation for objects within the virtual environment. This interactivity was mentioned as a need during the final Field Trials and is one of the next development steps of the system.

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6 SHOTPROS User Experience Studies and Field Trials

The guidelines presented in this document were informed to a great extent by the results of several studies conducted during the project. In this chapter, these are summarised, together with the implications that were drawn from it for the SHOTPROS VR solution and for future requirements of a VR training system for police officers. The studies can be divided into three categories: (1) user experience and LEA feedback studies with the SHOTPROS VR solution, (2) studies concerned with the materialisation of stressors and (3) studies regarding possible behavioural performance indicators. The findings of these studies were used to define the guidelines in chapter 5.

6.1 User Experience (UX) studies

Throughout the course of the SHOTPROS project, the same core questionnaire (see Table 1 for overview) was attached to all studies regarding user feedback of the system. The first page of the core questionnaire was meant for general feedback, with partly open questions. Page two focused on evaluating the training experience in detail, with items from different validated usability questionnaires. The UX studies, often executed as part of the End User Feedback Weeks (see D6.1 and D4.6) played a major role during the project, as they provided regular feedback of the progress and the most pressing next steps needed for improvement. The complete questionnaire can be found in the appendix of this document.

No.	Item	Answer modality
1	Overall quality of experience with the VR system	5-point Likert Scale
2	Problems with the system	Yes / No
3	If "Yes" at question 2, please describe them.	Open answer
4	What was positive / worked well?	Open answer
5	What was negative / did not work well?	Open answer
6	What are your ideas to make the system better?	Open answer
7	Demographics (Role, Gender, Age, Years of experience)	Categorical
8	Items relating to training experience: • Perceived Ease of Use • Immersion • Imagination • Intention to Use • Quality of Learning • Use case police – specific items	5-point Likert Scale

Table 8: Structure of the core questionnaire of all user experience studies.

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Ease of Use, Immersion, Imagination and Intention to Use are all item scales adapted to VR that are part of the Technology Acceptance Model[3], which is designed to measure the adoption of new technology based on users' attitudes. Quality of Learning describes two items relating to how much of the training can be transferred into. Further, three items specific to the use case of police training were included. See Table 9 for a detailed listing of scales in the questionnaire.

Scale	Description	Likert scale
Perceived ease of use	Measures how easy it was for the participants to learn how to use the virtual training environment, and how easy it was for them to use the virtual training environment.	**1** (doesn't apply) – **5** (fully applies)
Immersion	Measures to what extend could the participants immerse themselves in the virtual environment, how realistically they perceived other people in the VR, and whether the training scenario seemed realistic to them.	**1** (doesn't apply) – **5** (fully applies)
Interaction	Measures to what extend could the participants move naturally, orient themselves easily, and handle objects realistically in the virtual environment.	**1** (doesn't apply) – **5** (fully applies)
Intention to use	Measures whether the participants are willing to use the virtual environment in their future trainings.	**1** (doesn't apply) – **5** (fully applies)
Imagination	Measures whether the participants perceived the virtual environment as helpful to realistically experience their own vulnerability and that of others, and helpful to better understand critical operations.	**1** (doesn't apply) – **5** (fully applies)
Quality of learning	Measures whether the participants perceived the virtual environment as a useful training strategy to help them later in real operations, and helpful to better cope with similar situations in practice.	**1** (doesn't apply) – **5** (fully applies)

[3] King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management*, *43*(6), 740–755. https://doi.org/10.1016/j.im.2006.05.003

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Useful addition	Measures whether the participants think virtual trainings are a useful addition to the other police trainings	**1** (doesn't apply) – **5** (fully applies)
Better than real	Measures whether the participants think the virtual environment offers better training opportunities than real training.	**1** (doesn't apply) – **5** (fully applies)
Useful tool	This scale intended to measure whether the participants perceived the virtual environment as a useful training tool for police.	1 (doesn't apply) – 5 (fully applies)

Table 9: Scales and Items used in the LEA feedback questionnaire.

6.1.1 Results

In the following chapter, the results of the UX studies will be presented. As overall visualisations we chose boxplots as they give a good representation of the distribution of data.[4]

6.1.1.1 Overall Results

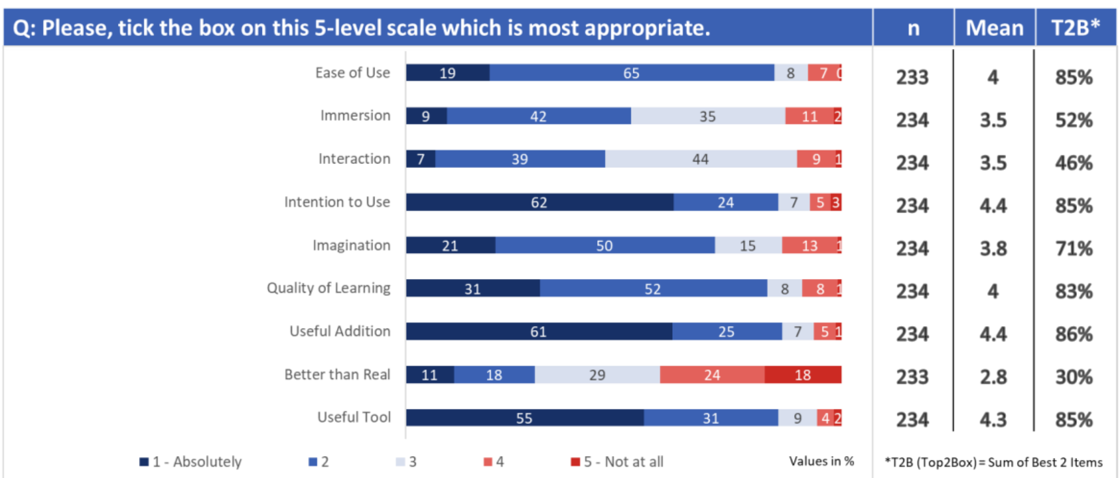

Figure 31: Overall answers for the scales across all Field Trials and Human Factors Studies.

[4] A boxplot is a standardised way of displaying the distribution of data based on a five number summary ("minimum", first quartile [Q1], median, third quartile [Q3] and "maximum"). Boxplots can also inform about outliers and what their values are. The box itself marks the range, in which 50% of all values lie, whereas the ends of the lines signify the minimum and maximum value of the distribution. The interquartile range (IQR) describes the range from the bottom to the top of the box. The horizontal line in the boxplot signifies the median of the distribution, i.e. the value where half the values are smaller and half are bigger than the median. Outliers are marked with dots.

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Across the five FTs, five of the scales were rated very positively, with T2B values of >85%. For one, the two police-specific questions **"Useful Addition"** and **"Useful Tool"** were both rated 86% and 85% respectively as good or very good. This indicates, that overall the SHOTPROS VR solution is regarded as a very good complimentary solution for training, and is a very good tool to achieve training goals efficiently. Further, **"Ease of Use"** was rated overwhelmingly positive (85% rated either very good or good), which demonstrates that the developed solution is easily used by the trainees, is intuitive and can be learned quickly. **"Intention to Use"**, which is a good predictor whether a system would be used in everyday work, was also rated with 62% as very high and 24% as high (85% T2B), which shows that most of the trainees are very eager to use the SHOTPROS system in their training curriculum. 83% of all trainees rated the **"Quality of Learning"** as high or very high. This illustrates, that the trainees rated the transfer of crucial knowledge and skills for decision making and acting into reality as very positive. **"Imagination"** was mostly rated positive as well (71% T2B), so the system generally helps to visualize critical situations well and makes it possible to experience one's vulnerability in a safe environment.

The **"Immersion"** items were rated a bit more temperate: with a mean rating of M = 3.5, trainees rated their immersion in the VR environment as moderate to good (52% T2B). **"Interaction"** was rated similarly (M = 3.5), with most trainees rating the system as moderate to good in terms of interaction with virtual objects and natural movement in the virtual environment. The results of these two scales show, that the system fulfils basic requirements of immersion and interaction, with room for further improvement. These results built the base for the decision to develop the much more immersive environment based on the Unreal graphic environment and testing additional materialisation approaches of stress like the integration of scent, feelable options like wind or heat and pain stimulus.

The item **"Better than Real"** was rated more diversly, with only 30% agreeing completely or simply agreeing to the VR training being better than real training. This result though was expected, as the SHOTPROS VR solution is intended as addition to the training curriculum of police officers, and not as a replacement. Qualitative feedback from the FTs further supports this argument, as many trainees stated regarding this question, that they would not say either real or virtual training was better, but that it depends on what is being trained.

6.1.1.2 Field Trial Results

In this chapter we will discuss the results of the FT in general and per each FT.

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6.1.1.2.1 Quality of Experience

The overall quality of experience with the system was rated with a single item, and serves as a summary grade for the system, including the actual training in VR, but also the organizational aspects around it, like putting on the suit, calibrating the system or the AAR. On the scale from 1 (excellent) to 5 (deficient), most participants from the trial groups FT 01, FT 02, FT 03, and FT 05 rated the quality of the training as **2** (good) (Median = 2) and most participants from the trial group FT 04 rated it as 3 (ordinary) (Median = 3). The ratings from the trial group FT 01 were less spread over (IQR = 2-2) compared to the other trial groups, meaning **the large majority of participants rated the system as good**. Field Trial 4 and 5 were held in Selm and Berlin respectively, where the SHOTPROS system was already tried out during the human factor studies. This explains the slightly lower ratings for overall quality of experience as more ordinary, as the participants already knew the system. In summary the overall experience with the SHOTPROS system was therefore rated as good.

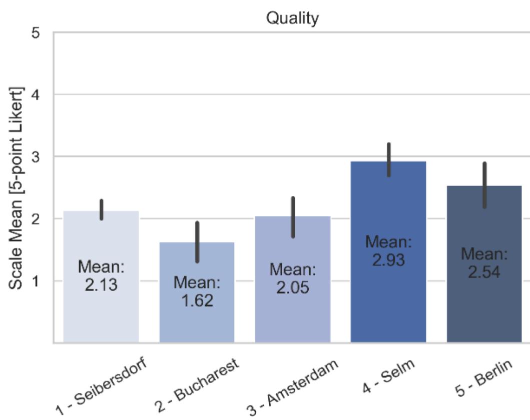

Figure 32: Bar plots of overall quality of experience (QoE) across the 5 Field Trials. Lower values indicate more positive ratings

6.1.1.2.2 Positive Aspects of the Training Environment

1 - Communication	22
Communication with operator/colleagues/teamwork	13
Introduction to the system/explanation	8
Addressing perpetrators	1

5 - Equipment	8
Firearms / shooting	2
Technology has worked	1
Posture feedback	1

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2 - Scenarios & Environment	**21**
Good scenarios/variety of scenarios/possibilities in scenarios	11
Perception of the environment	6
Positioning of the bystanders	1
Stair climbing nicely implemented	1
Opening doors nicely implemented	1
3 - Immersion	**15**
Immersion was very good/VR realistic/scenarios close to reality	8
Sense of space	1
Display of fire	1
Good graphics	3
You could focus exclusively on the police action	1
Stress levels	1
Positions	1
4 - Measurement & Statistics	**8**
Movement in space/orientation	5
New possibilities, perspectives and analysis options for feedback	1
Accuracy and agreement/acclimation	1
Evaluation	1
Roll up of the equipment	1
Motion detection	1
The EMS was displayed every time I pulled it	1
Feeling equipped to act/ put oneself in the position	1
6 - Other	**8**
High expectations in advance, you do not know exactly what will happen	1
It has worked as a whole	1
The use of the resources has worked well	1
Potential opportunities	1
Good but some things need improvement	1
The program ran flawlessly	1
Experience gained	2

Table 10: Positive aspects of training environment, study results

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6.1.1.2.3 Scales

In this chapter, the results from the scales explained in Figure 33 will be presented for the five FTs. Figure 33 shows boxplots of every scale for every FT. Overall, the participants of the different FTs rated the system very homogenously across the scales of the questionnaires, with one exception: Participants of the FT 2 in Bucharest tended to rate even more positively than participants of the other four FTs. An explanation for that night be that the participants there had the least experience with scenario training itself (independent of VR) and were also very positive towards the training type itself and therefore probably rated the full experience higher than others. Another reason is also that the SHOTPROS system was not tested by the participants before (like 3 other FTs).

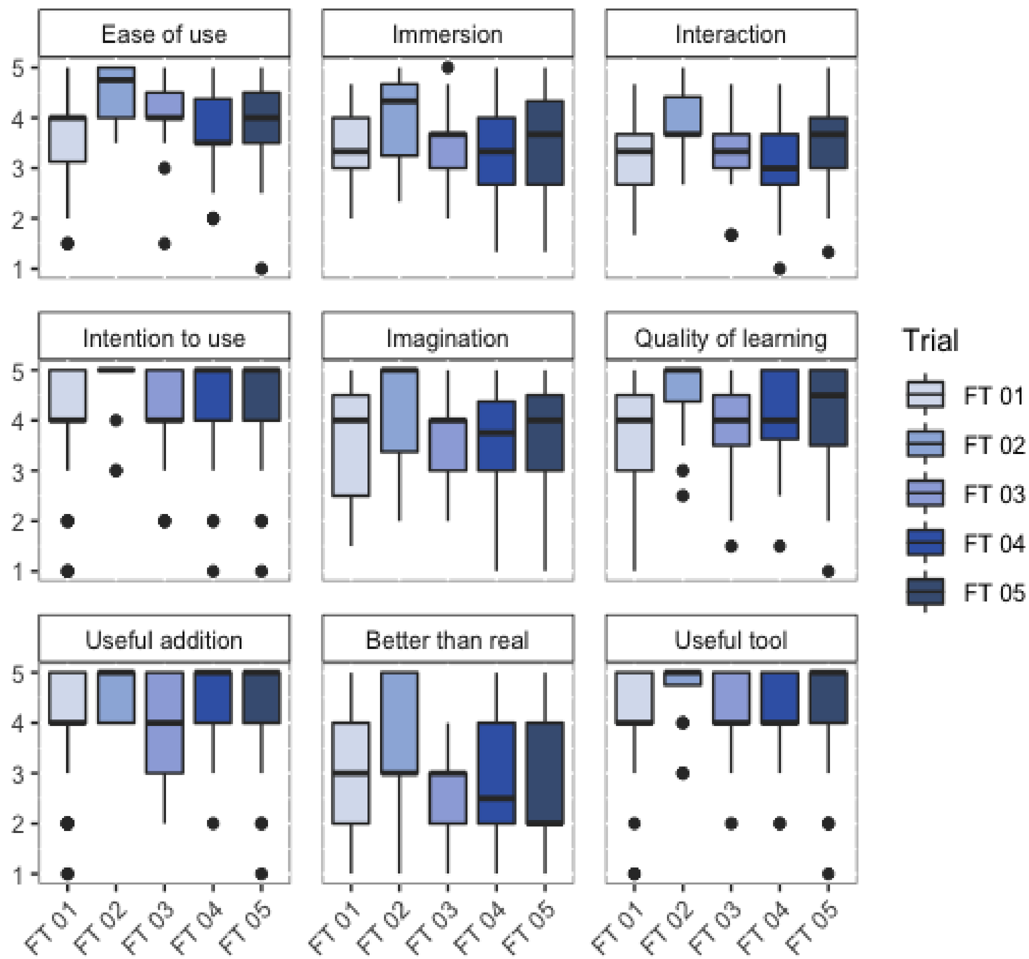

Figure 33: Boxplots of all scales of the LEA feedback questionnaire for all five field trials.

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Perceived ease of use

Perceived ease of use describes a central aspect of the usability of the system, namely how easy or intuitive it is to use it. In the context of the SHOTPROS system, this would mean how easily the trainees got used to moving, interacting and communicating in the VR training. Figure 34 presents the means of this factor in a bar plot for all 5 FTs.

On the scale from 1 (doesn't apply) to 5 (fully applies), most participants in the trial groups FT 01, FT 03, FT 04 and FT 05 rated the "Ease of use" as **4** (FT 01: Median = 4, FT 03: Median = 4, FT 04: Median = 3.5, FT 05: Median = 4) and most participants from the group FT 02 rated it as 5 (Median = 4.75). There was little difference in within-group variation of the ratings. The vast majority of participants therefore found the SHOTPROS system **easy to very easy to use** and could learn how to operate it quickly and easily. One trainee's comment illustrates the consequence of the ease of use very well: **"You could focus exclusively on the police action, without being distracted by the technicalities"**. A big role in the perception of ease of use was also the good introduction to the system: "The thorough explanation and introduction was very helpful, **I could then use the system without problems**."

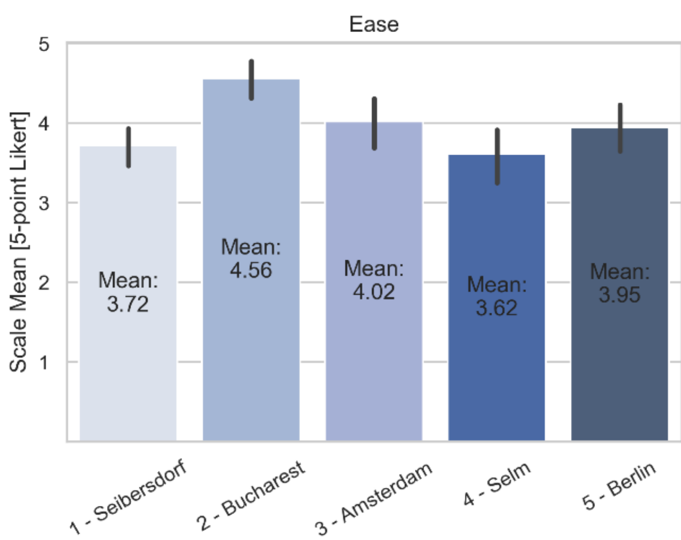

Figure 34: Barplots of the factor "Ease of Use" for the 5 Field Trials.

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Immersion

Immersion describes how realistic and natural the VR simulation felt to the participants. High immersion means, that trainees were able to involve themselves in the simulation and in a way forget their real surroundings to accept the "illusion" of VR as real. On the scale from 1 (doesn't apply) to 5 (fully applies), most participants in the trial groups FT 01 and FT 04 rated the "Immersion" as **3** (Median = 3.33) and most participants from the groups FT 02, FT 03, and FT 05 rated it as **4** (FT 02: Median = 4.33, FT 03: Median = 3.67, FT 05: Median = 3.67). The ratings from the trial group FT 03 were less spread over (IQR = 3.67-3) compared to the other trial groups. The immersion experienced by the participants with the SHOTPROS system was therefore rated as **adequate and good** across the five Field Trials. Verbal feedback from the trainees indicates, that the felt immersion stemmed from "realistic scenarios" which were "close to reality", in the sense of the "good graphics" and the "sense of space". Also, the use of realistic firearm props and the tactical belt were mentioned as positives regarding immersion.

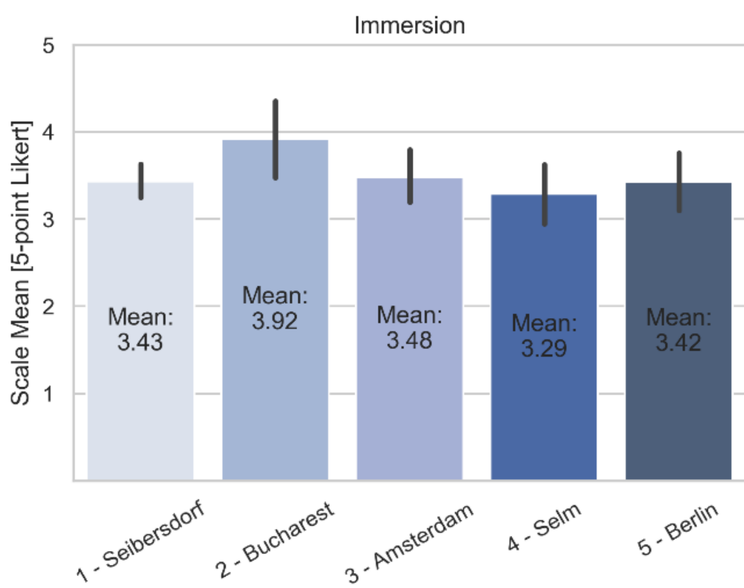

Figure 35: Barplots of the factor "Immersion" for the 5 Field Trials.

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Interaction

The factor interaction describes, how well the participant could **interact** with the virtual environment, be it by moving or interacting with virtual objects or other trainees in the scenario. On the scale from 1 (doesn't apply) to 5 (fully applies), most participants from the trial groups FT 02, FT 04, and FT 05 rated the "Interaction" as **3** (FT 01: Median = 3.33, FT 04: Median = 3.33, FT 05: Median = 3) and most participants in the trial groups FT 01 and FT 03 rated it as **4** (Median = 3.67). There was little difference in within-group variation of the ratings. This shows that interaction and movement within the VR training was rated as **adequate and good** by the majority of trainees. As mentioned in chapter 5.6, one **challenge** associated with this factor is the interaction with and **handling of objects** in the virtual environment. Trainees partly mentioned, that e.g. opening doors needs some getting used to, or that they were not sure which objects they could pick up. Also, interaction with their teammates was perceived as a difficulty at times, in the sense of touching them e.g. at the shoulder. This ties into to the calibration challenges of the system, as having the person in the exact position as their avatar requires a very fine precision.

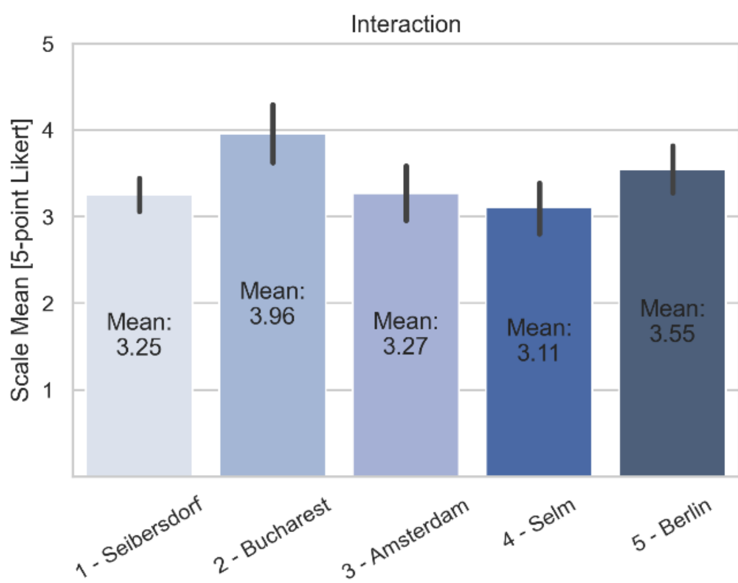

Figure 36: Barplots of the factor "Interaction" for the 5 Field Trials.

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Intention to use

Intention to use is a classical UX question, where the trainees rate, whether they would use the system in the future. This factor is of special importance, as it indicates the likeliness of such a system being acquired. On the scale from 1 (doesn't apply) to 5 (fully applies), most participants from the trial group FT 01 and FT 03 rated the "Intention to use" as **4** (Median = 4) and most participants from the trial group FT 02, FT 04, and FT 05 rated it as **5** (Median = 5). The ratings from the trial group FT 03 were less spread over (IQR = 5-5) compared to the other trial groups. These **positive results** show, that trainees fully support using the system in the future and intend to train with it.

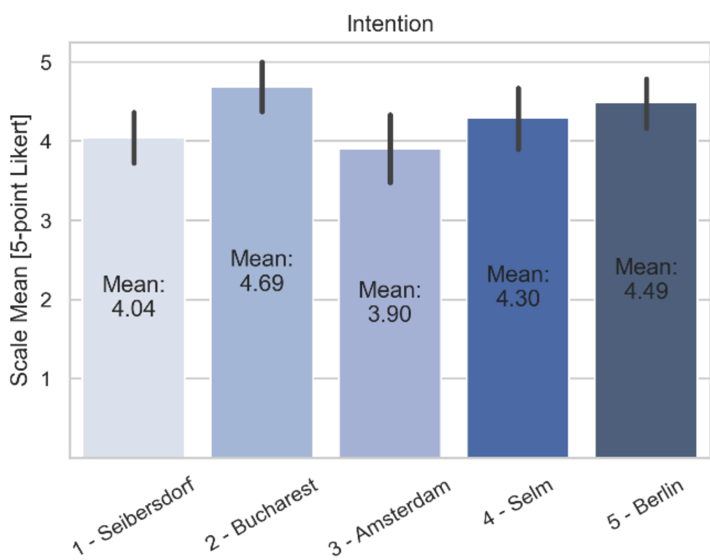

Figure 37: Barplots of the factor "Intention to Use" for the 5 Field Trials.

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Imagination

Imagination is another practical scale, where trainees rate, how the virtual environment helps to **better understand critical operations** and their own and others vulnerability in them. On the scale from 1 (doesn't apply) to 5 (fully applies), most participant from the trial group FT 01, FT 03, FT 04, and FT 05 rated the "Imagination" as **4** (FT 01 & FT 03 & FT 05: Median = 4, FT 04 = 3.75) and most participants from the trial FT 02 rated it as **5** (Median = 5). These **good to excellent ratings** demonstrate, that the SHOTPROS system offers **unique experiences**, that help imagine critical situations and learn from them. Trainees reported that they had "gained experience after the training sessions" and experienced "increased stress levels". Also the "new possibilities", "perspective taking in the analysis" and the "analysis options" were experienced as valuable teaching tools. Another feedback comment was, that trainees "felt equipped to act" and were enabled to "put oneself in the position".

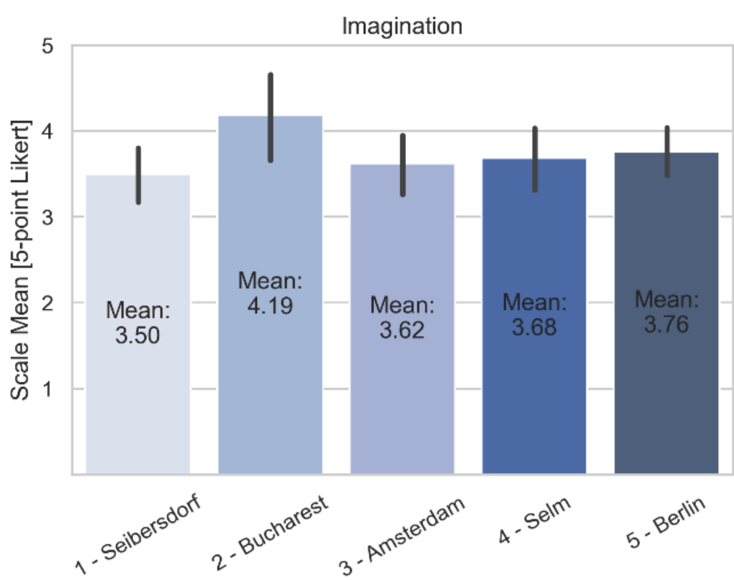

Figure 38: Barplots of the factor "Imagination" for the 5 Field Trials.

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Quality of learning

Quality of Learning describes whether trainees felt like the could **transfer gained knowledge** and experience from the VR training to the real world, and whether it would help them cope with similar situations. On the scale from 1 (doesn't apply) to 5 (fully applies), most participants from the trial group FT 01, FT 03, and FT 04 rated the "Quality of learning" as **4** (Median = 4) and most participants from the trial group FT 02 and FT 05 rated is as **5** (FT 02: Median = 5, FT 05: Median = 4.5). The ratings from the trial group FT 02 were less spread over (IQR = 4.5-4.38) compared to the other trial groups. The **positive to excellent ratings** for quality of learning show, that the system enables a learning transfer and has an impact in real world situations – which is the major goal of the training system. The possibilities of "variety of scenarios" and "different possibilities" within the scenarios was mentioned as positive points regarding the quality of learning, as was the "communication with colleagues" which enabled the "training of teamwork.

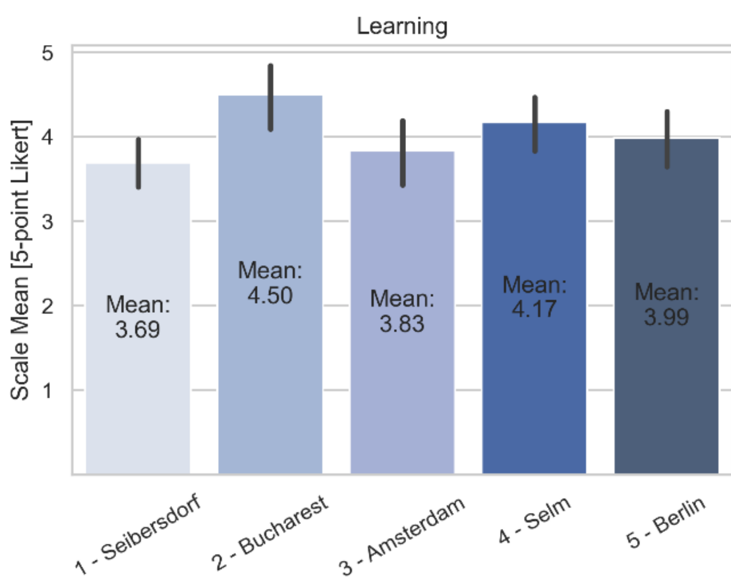

Figure 39: Barplots of the factor "Quality of Learning" for the 5 Field Trials.

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Useful addition

For this single item, trainees rated whether the SHOTPROS **system would be a useful addition to existing training methods**. On the scale from 1 (doesn't apply) to 5 (fully applies), most participants from the trial group FT 01 and FT 03 rated the "Useful addition" as **4** (Median = 4) and most participants from the trial groups FT 02, FT 04, and FT 05 rated it as **5** (Median = 5). The ratings from the trial group FT 03 were more spread over (IQR = 5-3) compared to the other trial groups. The **extremely positive ratings o**n this item demonstrate, that the vast majority of trainees would include the SHOTPROS system in their training curriculum as a very useful addition.

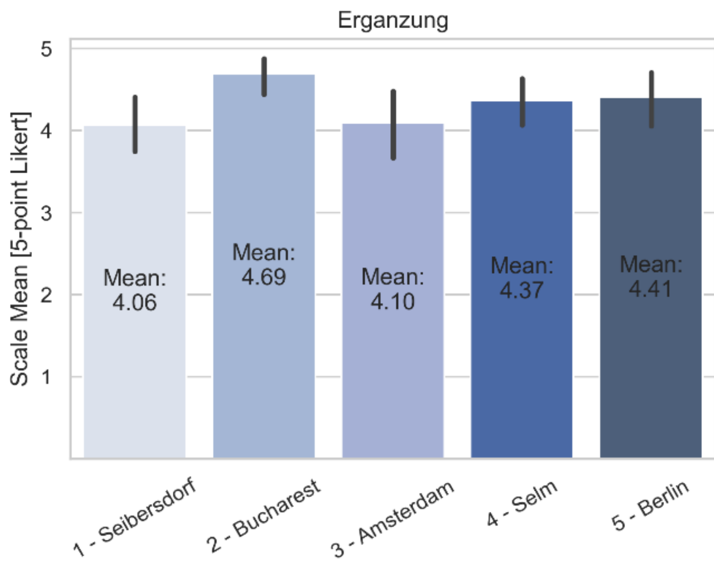

Figure 40: Barplots of the factor "Useful Addition" for the 5 Field Trials.

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Better than real

For this item, trainees should rate **whether the VR training was better than real life training**. On the scale from 1 (doesn't apply) to 5 (fully applies), most participants from the trial group FT 05 rated the "Better than real" as **2** (Median = 2) and most participants from the trial group FT 01, FT 02, FT 03, and FT 04 rated it as **3** (FT 01 & FT 02 & FT 03: Median = 3, FT 04: Median = 2.5). Trainees therefore saw real life training and the SHOTPROS VR training on a similar level – which further supports the ratings from the item "useful addition": the SHOTPROS system is an addition and complement to existing, real life training methods. Therefore, **neither one is better, but each is useful in its own respect.**

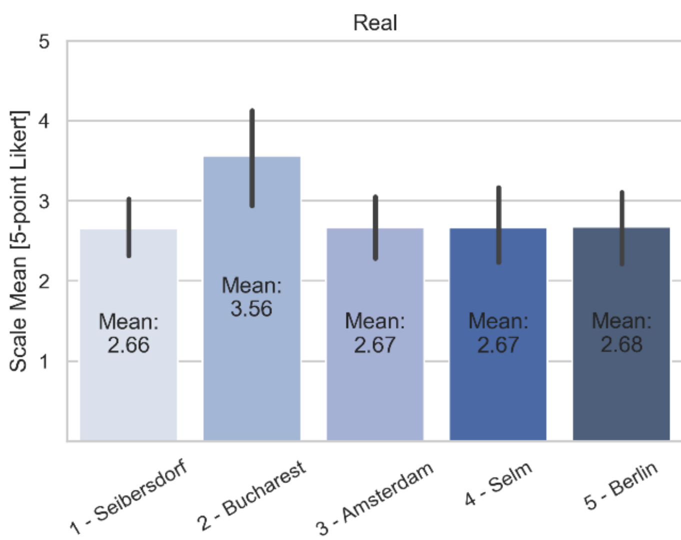

Figure 41: Barplots of the factor "Better than Real" for the 5 Field Trials.

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Useful tool

The last police specific item was, **whether the SHOTSPROS system is a useful tool for police training**. On the scale from 1 (doesn't apply) to 5 (fully applies), most participants from the trial group FT 01, FT 03, and FT 04 rated the "Useful tool" as **4** (Median = 4) and most participants from the trial group FT 02 and FT 05 rated it as **5** (Median = 5). The ratings from the trial group FT 02 were less spread over (IQR = 5-4.75) compared to the other trial groups. The **positive to excellent results** here show, that the SHOTPROS system is considered very useful for police training, which further confirms the results from "useful addition" and "better than real".

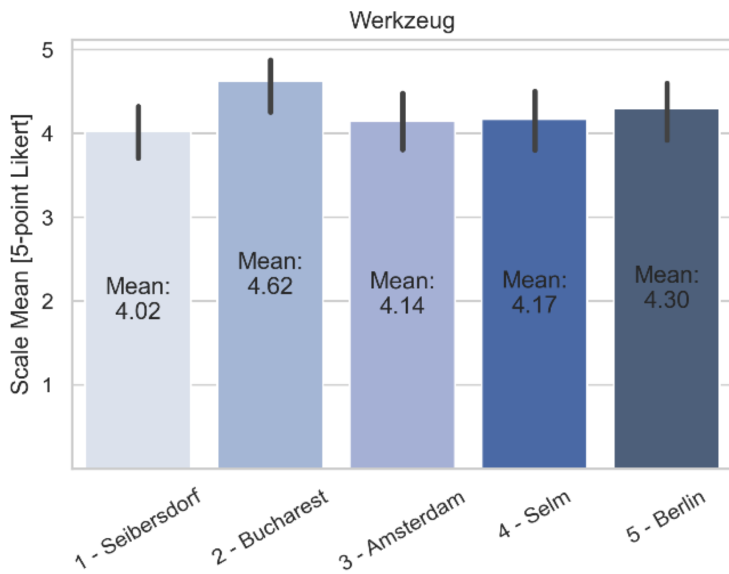

Figure 42: Barplots of the factor "Useful Tool" for the 5 Field Trials.

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6.1.2 Comparison with Earlier Development States

Key findings of qualitative data from the HF studies served as the basis for the continuous agile development process of the SHOTPROS system (see D4.6). One major finding of improvement from earlier version was the experienced **cyber sickness**. While being a point of criticism in the earlier versions during the human factor studies, no trainee reported cyber sickness in the last version used during the Field Trials. Also, when compared to the human factor studies, the **clearness of view** was not mentioned as a problem anymore, which was likely to due to improvements in graphical quality. The **calibration of the pistol** was mentioned as not correct enough during the human factor studies, whereas during the Field Trials this was not mentioned anymore. Other calibration issues remained the same, as the visualisation of distances, which is more a general VR issue than a specific issue of the SHOTPROS VR solution. All in all, the development and improvements made from the human factor studies were well received during the FTs, while some challenges remain (see chapter 5.6). Figure 43 presents the boxplots for this comparison.

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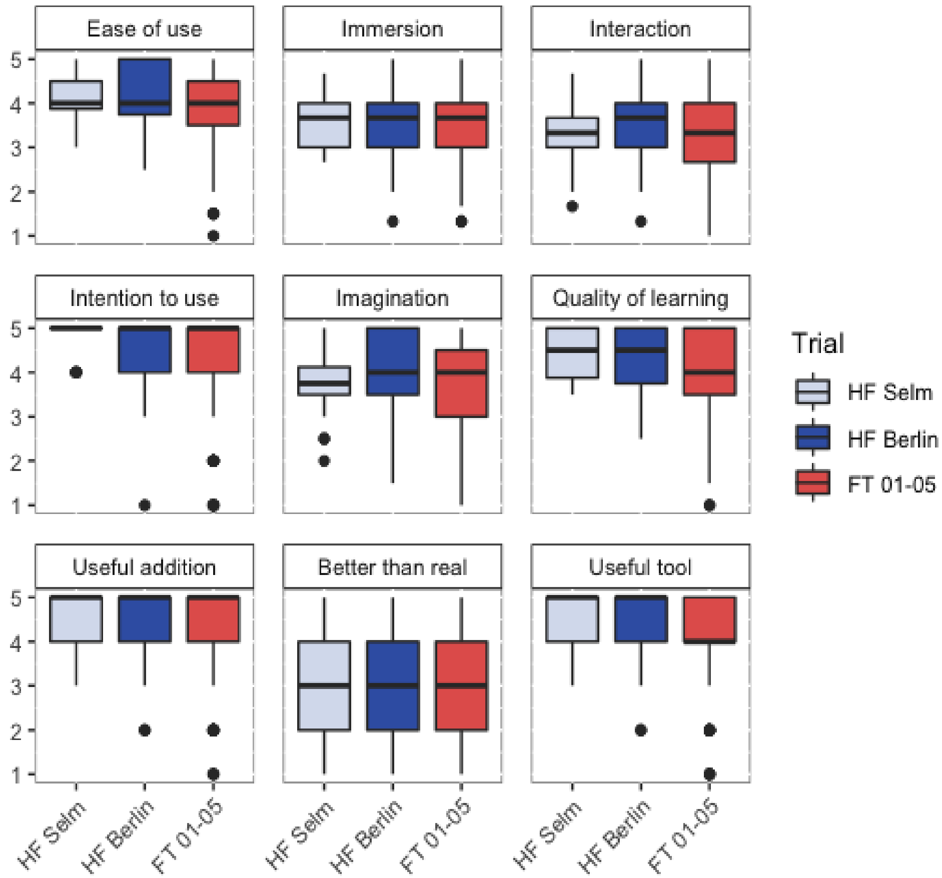

Figure 43: Boxplots of all scales of the LEA feedback questionnaire for the two HF studies and the combined results of all field trials

6.1.3 Summary of UX Studies

Overall, the results from the UX studies show, that all goals of the SHOTPROS project regarding user experience were fulfilled from the end user's perspective. Especially the factor „Intention to Use" received the highest rating from all factors (**Mean = 4,3**), which illustrates the need and willingness of the end users to use and implement the SHOTPROS system in the future. The system is seen as a useful tool for police training, which can be implemented in existing training curricula for DMA-SR training. The end-users further reported a high quality of learning, indicating that the learning transfer to reality is expected to be high. The "Better than real" and "Useful tool" factors further illustrate, that end users see VR training as an addition for existing training and not as a replacement, which is exactly how it is intended.

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For further development of the system to TRL 9 the evaluation delivered valuable learnings. To improve from the current TRL 6 to TRL 9, the factors of immersion and interaction have to be further developed. Regarding interaction, this will mainly mean improving the calibration process and accuracy, and further increasing the experienced realism of the training. The guidelines presented in this deliverable are a result of these studies, as they indicate future developments in VR training for police. To improve upon the factor "Imagination", i.e. experiencing vulnerability in different situations, our research in the direction of multi-sensory enhancement of the VR and the materialization of stressors presented chapter 6.2 shows great promise.

Scales		Median 1 (doesn't apply) - 5 (fully applies)
Perceived ease of use	How easy is it to use	4/5
Immersion	How realistic and natural the VR simulation feels	3/4
Interaction	how well the participant could interact with the virtual environment	3/4
Intention to use	whether they would use the system in the future	4/5
Imagination	how the virtual environment helps to better understand critical operations and their own and others vulnerability in them	4/5
Quality of learning	transfer gained knowledge and experience from the VR training to the real world	4/5
Useful addition	system would be a useful addition to existing training methods	4/5
Better than real	whether the VR training was better than real life training	2/3
Useful tool	whether the SHOTSPROS system is a useful tool for police training	4/5

Table 11: Scales results - overview

6.2 Stressor materialisation studies

The dynamic addition of the identified main stressors is one of the main components of the SHOTPROS VR solution. VR in its **current** form is mostly focused on displaying these stressors in two sensory modalities: the **visual** and the **auditory** sense. Certain elements in the police officers environment may be stressful due to a perceived threat that can be seen (e.g. a weapon) or heard (e.g. the barking of an aggressive dog), whereas others may stem from other sensory modalities. Entering a dirty building for example, may be perceived as stressful not because of how it looks, but how it smells. Similarly, modalities like wind or heat could be the triggers for a raise in stress level.

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To make the stressors more immersive and realistic, and to gauge the effects of adding these multi-sensory stimuli to stressors in the training, **two different studies** were conducted during the Field Trials of the project.

To augment certain elements in the virtual training with multi-sensory stimuli, the Mobile Multi-Sensory Platform (MMSP) was concepted and built by AIT. The MMSP is a physical device, that allows the administration of different sensory experiences: heat, wind, mist, vibration, olfaction, and light pain. Figure 44 shows the MMSP and its modules. The MMSP can be moved around to administer the required multi-sensory stimuli at the place it is needed based on the location of the virtual counterpart (e.g. a fire at a certain spot in the virtual environment). An integrated tablet serves as the window into the virtual reality, so that at any time the operator of the MMSP knows what is happening in the virtual training.

Figure 44: The MMSP and its modules (left), the interface of the MMSP (middle) and the external devices (shock band and olfaction devices - right).

6.2.1 Study 1: Context dependency of Multi-Sensory Stressors

Study 1 was conducted during the first FT in Seibersdorf, Austria, and had the aim of investigating, whether the addition of multi-sensory stimuli to stress-cues in VR **would lead to a stronger stress responds** in the trainees. Two of the trained scenarios were compared: In both scenarios, trainees would approach a hotel building from the outside – with the only difference being the weather. Scenario 1 featured a "neutral" weather, with blue sky and a few clouds (Figure 45b), whereas scenario 2 featured "bad" weather, with thick clouds resembling a storm (Figure 45a). As **bad**

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weather was one of the identified possible stressors, we enhanced both scenarios with wind for the experimental group (Figure 45c), and left it as is with the control group. Our hypothesis was, that enhancing the “good” weather would not lead to differences in perceived stress, whereas the “bad” weather should be more stressful if enhanced with wind.

As measurements, we let the trainees rate their experienced subjective stress on a visual analogue scale (VAS), where trainees would indicate on a continuous line from “not stressed at all” to “extremely stressed” how they experienced the respective scenario. Additionally, we used the heart rate variability of the trainees as a physiological indicator for stress, so support or hypotheses. This was captured with the Zephyr Bioharness, depicted in Figure 45 (d).

Figure 45: From left to right: (a) Depiction of the "bad" weather scenario, (b) depiction of the "good" weather scenario, (c) the MSP administering wind as a multi-sensory stimulus and (d) application of the Zephyr Bioharness.

6.2.1.1 Results

The results from study 1 are presented in Figure 46. As expected, the addition of **wind** led only to a significant increase of subjective stress ratings in the “bad” weather scenario, with it being **rated as nearly twice as stressful than without wind**. Similarly, the heart rate variability was significantly lower, when the “bad” weather was enhanced with wind than in the normal VR condition, but not when the “good” weather was enhanced (lower heart rate variability is associated with higher stress). These results illustrate, that **enhancing a stressor with multi-sensory elements can lead to an increase in perceived and physiological stress**, whereas the enhancement of non-stressful cues does not lead to a difference in stress. Therefore, multi-sensoric stressors could be a viable way, to increase the difficulty of a scenario, and make it more realistic for the trainees and by this achieving higher learning results.

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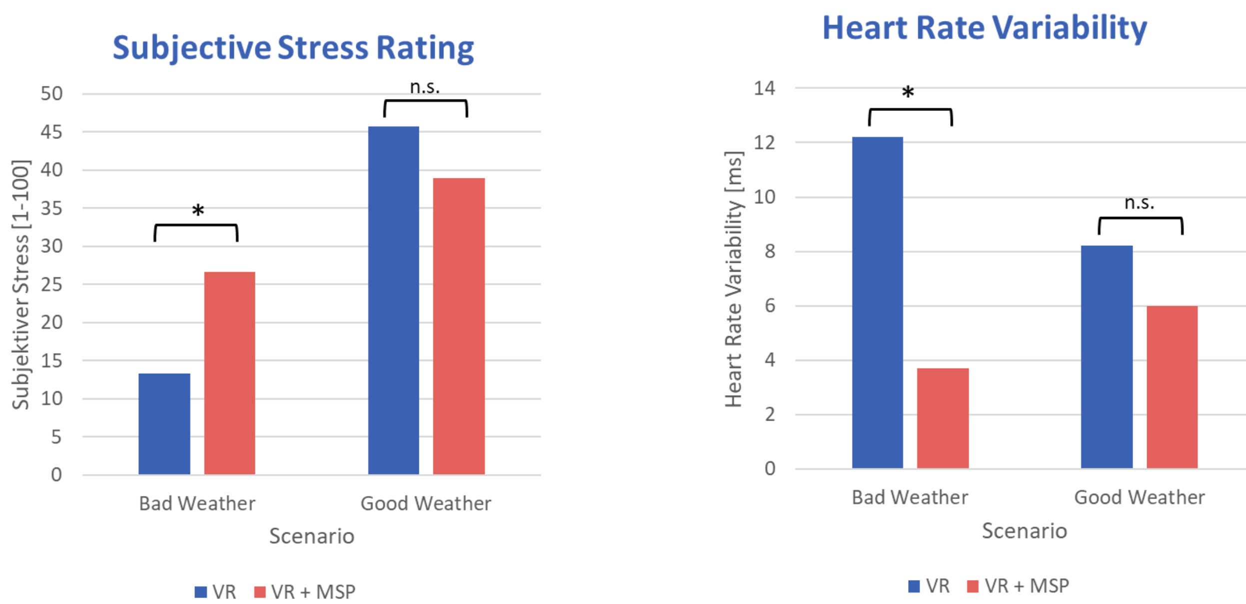

Figure 46: Bar plots of subjective stress ratings (left) and heart rate variability (right) for both scenarios and both conditions in study 1.

6.2.2 Study 2: Multi-sensory stressors with threat perception and perceived realism

During the FT in Bucharest first tests with integrating **scents** into the VR training were conducted. Using an olfactory device by OVR Technology[5] (Figure 47) different **stressors** where **highlighted with corresponding scents**: A puddle of water was enhanced with the smell of gasoline, a fire with the smell of smoke, and a perpetrator with the smell of sweat. To investigate **effects of more elaborate multi-sensory stressors (including wind, heat, smell and light pain),** we conducted a second study in both the Field Trials Selm and Berlin.

In this study, the aim was to investigate whether enhancing stress cues with multi-sensory stimuli would result in (a) an increase in perceived realism in general and (b) an increase in perceived threat, when stressors are enhanced. Again, we used visual analogue scales for perceived realism and perceived threat of three elements in the trained scenarios. A **street** (Figure 48a), that trainees had to cross in the beginning of the scenario served as a neutral element that was enhanced in for the multi-sensory group with

Figure 47: OVR scent device attached to the VR Headset

[5] https://ovrtechnology.com/

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wind, simulating the cars driving by. A perpetrator in the same scenario would pull out a knife (Figure 48b) and try to **stab** the trainee in the same scenario, which was timely enhanced with a light shock on the trainee's arm. In a second scenario, a bomb would go off on a public square (Figure 48c), which was enhanced with the smell of smoke combined with a heat wave generated by the MMSP (Figure 44) and try to **stab** the trainee in the same scenario, which was timely enhanced with a light shock on the trainee's arm. In a second scenario, a bomb would go off on a public square (c), which was enhanced with the smell of smoke combined with a heat wave generated by the MMSP.

(a) Neutral element: *(b) Stressor 1: Man* *(c) Stressor 2:*

Figure 48: Elements of the VR training in study two that were enhanced with multi-sensory stimuli. For the street (a) we included wind, for the knife attack (b) we included a pain stimulus, and for the explosion (c) a combination of heat, wind and smell was added

6.2.2.1 Results

The results of study 2 are summarised in Figure 49. Regarding realism, **all three elements** (street, stab, explosion) were rated significantly **more realistic when enhanced with multi-sensory** stimuli. **Especially the explosion** was rated around 30 points higher on the 1-100 scale when heat, wind and scent was added. Compared with the street, where only wind was added and a 12-point increase was found, this suggests that the addition of smell increases the realism of the training even further.

Regarding threat ratings, no significant difference was visible for the street. This was to be expected, as the street was included as a neutral element and not a stressor. The stab and the explosion on the other hand were rated as significantly **more threatening** when enhanced with **light pain** for the stab or **wind, heat and smell** for the explosion. This further suggests that the threat emanating from e.g. a knife is higher, when there is a chance of receiving an uncomfortable shock, which in turn leads to more realistic behaviour. This was supported by the trainees' comments on the shock: when

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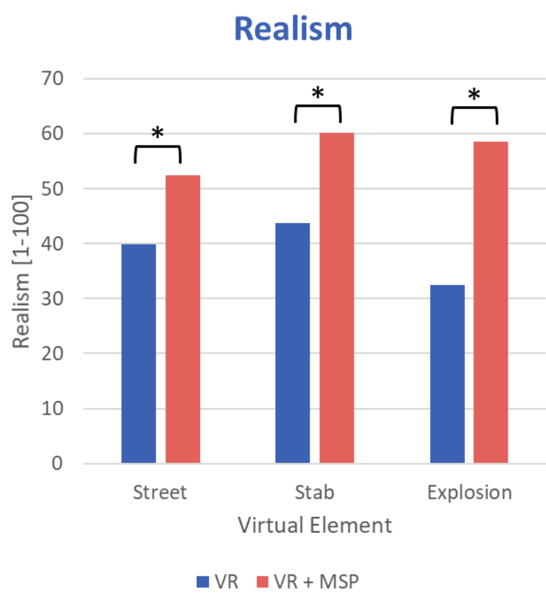
they were aware, that there could be a shock if they were hit, they tended to be more cautious and keep more distance from the perpetrator.



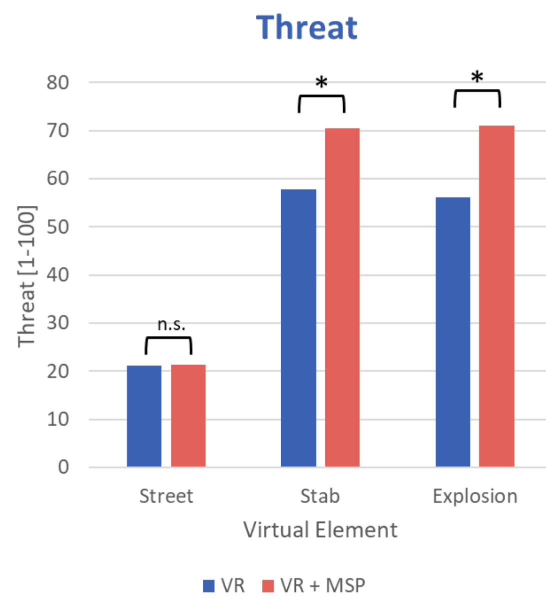


Figure 49: Bar plots of rated realism (left) and threat (right) of 3 elements in the VR scenarios, with and without multi-sensory enhancement.

6.2.3 Summary of Multi-Sensory Studies

Taking the results from study 1 and study 2 together, the **addition of multi-sensory elements to particular stressors shows great potential for making the training experience even more realistic**. Verbal feedback from the trainees supports this, as many trainees reported that they felt very immersed in the scenarios including wind / heat / pain and scent. Especially scent seems promising, as smelling certain uncomfortable scents often leads to strong emotional reactions, which increases the involvement with the training.

6.3 EU citizens on VR police training

Any VR solution that deals with the training of police officers in the safeguarding of citizens, should also view these citizens as ultimate stakeholders and consider their experience as input for VR training development. Therefore, in SHOTPROS, European citizens were consulted on issues such as their feelings of safety and security, perceptions about police and police performance and DMA. To

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gain this societal perspective, two online surveys have been administered to a total of 1390 European citizens.

In terms of **scenario development**, it is highly recommended to not only pay attention to the development of a specific offense or crime that takes place, but to also diversify in the following (reflected in the scenario guidelines - D7.7):

- Surroundings (e.g., poor versus rich neighbourhoods)
- Bystanders or victims (e.g., female versus male victims)
- The attitudes towards the police of the bystanders in the scenario, and how they interact with the police trainees (e.g., compliant versus disturbing the police work or filming)
- The chosen ethnicity, religion, and gender of the avatars who depict offenders, to avoid the risk of inducing implicit (racial) bias in police trainees

During (IAM) and after (AAR) training, trainers should pay attention to possible differences in how police trainees behave and (re)act in **different environments** and **towards different persons**. The results on this topic are reflected in D7.5, the VR training framework.

- About 7% of the EU citizens in our sample experienced some type of police use of force (mostly verbal aggression by the police). When training DMA-SR in the SHOTPROS VR solution, the training of proper **de-escalation techniques and verbal communication strategies** should also be **explicitly** targeted and discussed in the AAR.
- Findings from our survey suggest that citizens differ in what they deem the **most appropriate decision-making and acting** of police officers in specific situations compared to what is generally accepted as the most optimal decision-making and acting choice by LEA's.
- Furthermore, it was found that participants who watched the situations from the **perspective of the police officer** (body-cam video) systematically rated all the actions of the police officers as more legal, appropriate and proportional compared to participants who watch the situation from an observer perspective. This can potentially a future avenue to explore: using scenario-based VR solutions as a means to further educate citizens in why certain procedures are more optimal than others and to increase their understanding in how (threatening) certain situations can be perceived by the police officers. This can increase the citizens' perceptions of police and improve their attitude towards police officers.
- In general, **citizens feel that police officers lack sufficient training time** to be fully prepared to deal with stressful and/or high-risk situations in the field. **They also see great added value in the use of VR for** the basic **training** and 'on-the-job' training of police officers. This shows

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that EU citizens greatly support the idea of implementing VR training in the training curricula of police officers. Information like this is important for the introduction of VR training in an organisation (see D8.5).

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7 Future Development of VR Training Systems

Based on the implemented innovation features and the evaluation of them throughout SHOTPROS, a requirements and needs have been identified that need to be targeted in follow-up projects and/or the exploitation of the SHOTPROS VR solution into a product.

To summarise the knowledge gained in this project and potentially guide future projects or developments we will be discussing the most impactful features in this chapter.

7.1 Inclusive Performance Management System & Training Personalisation

Moving away from the "one size fits all" approach, the training industry (like many others) is shifting its focus to consider individual needs, wishes and capabilities. By adapting the learning path to a trainee's experience, current role, skills and fitness levels, individuals can train in scenarios that challenge them on the right level. Their track record should be recorded in and connected to the overall performance management system the LEA is using and not in isolation.

Benefits include:

- Higher engagement rates through challenging yet possible scenarios
- Better retention through enough repetition and training of the right difficulty level
- Targeted training to rank, location and experience level
- Motivation to pursue learning
- Trainee satisfaction

For VR training within LEAs this would require a centralized data storage system that is connected to the VR training system and ideally also includes personal information on training history (not limited to VR), experience level, skills and gaps. Considerations regarding data storage and privacy regulations appropriate for the LEAs individual country and standards might differ from one to another. We therefore strongly recommend consulting with your data protection officer and IT department when considering different VR training solutions (also see D8.5).

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7.2 High-End Content Streaming

The majority of currently used full-body VR solutions require users to wear a backpack that holds a computer necessary to power the VR headset. With the development of high-end streaming directly into the headset, trainees would be able to move more freely and strand back-to-back, without having the backpacks in-between them, a limitation that has been discussed frequently with the current SHOTPROS solution.

VR content can be streamed via a local Wi-Fi network, if there is a central training location or via the internet through cloud-based data storage, which enables multiple locations accessing the same "scenario library".

Both options come with their advantages and challenges.

With VR streaming, data throughput is currently one of those challenges. High Definition (HD) VR content requires high bandwidth. Factors effecting bandwidth requirements include resolution, frame rate, colour depth and field of view (FOV) which in turn effect quality of experience and level of immersion. Even though this may change in the near future, with currently available technology and hardware (e.g. headsets) it is often necessary to make trade-offs between the above mentioned factors, especially when considering more mobile or cloud-based solutions.

The current SHOTPROS solution works via a local WiFi network but in the future such training solutions would benefit from a connection to a cloud-based library to share best practise scenarios amongst different training centres. This would also enable the use of a compact version of the VR training system outside the training facilities such as police stations or even use at home. Although this might not be beneficial to train DMA scenarios, it would enable trainees to practice other skills.

7.3 Artificial Scenario Control

With artificial scenario control, scenarios could automatically adapt to the trainees needs. For example, trainees in low stress levels could be exposed to additional stress cues. Feedback from field trials suggests keeping the trainer in the loop as a safety measurement. If the process would be fully automated the danger occurs to overload trainees if for example, their baseline recording was not correct and therefore the calculated stress level is faulty. However, a solution could be developed that provides the trainer with suggestions based on current stress levels, previous experience and training history.

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7.4 Multi-Sensory Materialisation of Stressors

Multi-sensory stimuli enable the detection of environmental threats and injuries, that are otherwise hard or impossible to portray audio-visually alone. Scents of dangerous gases, liquids or fire sources are important factors when assessing the threat of a given situation, which is made possible with multi-sensory VR. The platform developed in SHOTPROS is a prototype that has to be operated manually. The goal here must be to develop a system that is directly integrated into the VR system and can be controlled with it. The platform can be stationary, which makes it necessary to adapt the scenarios accordingly or to move the platform to the respective position at the start. A mobile robotic platform would be optimal here, in order to reinforce several sources of danger with multi-sensory stimuli. However, this requires a reliable and safe system to avoid collisions with the trainees.

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8 Conclusion

This deliverable highlights the most important technical aspects of hardware, software and resource requirements for VR DMA-SR training and provides guidelines on selecting or developing a VR training solution that is an ideal fit to DMA-SR and the LEAs individual training needs. Several components and features of the SHOTPROS VR solution have been identified as absolutely necessary, such as full body tracking, a tactical belt closely resembling the real version the officers use, realistic scenarios, the possibility for quick and easy adaptation, stress assessment and induction options or natural movement to feel fully immersed as well as the detailed options of an AAR for better and more concise feedback to the trainees in order to enhance the learning effects.

To provide a thorough picture of requirements and relevant feedback, rather than selected opinions, a range of scientific studies have been conducted with a variety of industry experts, academic partners and most importantly six end-user partners (Polizei Berlin, Polizei Nordrhein-Westfahlen, Politie Netherlands, Police Romania, Polisen Sweden, Belgium Crisis centre). The feedback provided during these interactions and presented in the technical requirements (D4.6) and summarised over the project in the deliverable at hand, gave the technical partner the opportunity to develop and continuously improve the system, highly relevant for police training and identify current gaps from a technological perspective for further exploitation. These studies included explorations into the topic of **multi-sensory enhancement of stressors**, which proved promising to increase the realism, stress experience and threat perceptions of trainees during the trainings. The more general user experience studies spanning all Field Trials and human factor studies resulted in positive to very positive ratings in most measured experience factors, and uncovered potential developments for raising the TRL from the current level 6 to 9.

The most significant technical innovations of the project SHOTPROS including the Live Editor, Tactical Belt, Virtual Character Control, Real-time Stress Dashboard (Monitoring & Manipulation) and Performance Management (Stress & KPIs) during IAM and AAR have been highlighted and discussed.

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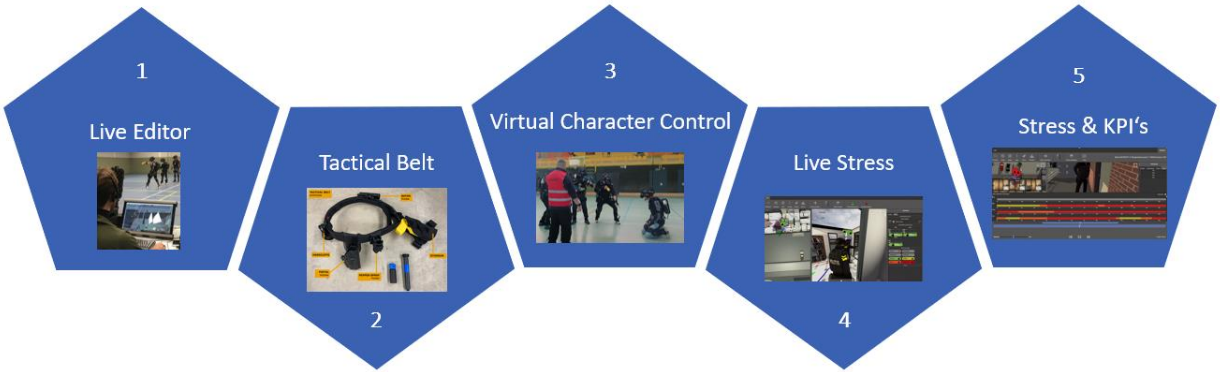

Figure 50: SHOTPROS Training System Innovations Overview

Topics that surfaced during field trials but were out of scope for the project are summarised in chapter 0 Any VR solution that deals with the training of police officers in the safeguarding of citizens, should also view these citizens as ultimate stakeholders and consider their experience as input for VR training development. Therefore, in SHOTPROS, European citizens were consulted on issues such as their feelings of safety and security, perceptions about police and police performance and DMA. To gain this societal perspective, two online surveys have been administered to a total of 1390 European citizens.

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During (IAM) and after (AAR) training, trainers should pay attention to possible differences in how police trainees behave and (re)act in **different environments** and **towards different persons**. The results on this topic are reflected in D7.5, the VR training framework.

- About 7% of the EU citizens in our sample experienced some type of police use of force (mostly verbal aggression by the police). When training DMA-SR in the SHOTPROS VR

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solution, the training of proper **de-escalation techniques and verbal communication strategies** should also be **explicitly** targeted and discussed in the AAR.

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Future Development of VR Training Systems and include topics such as the challenge of integrating VR training into overall performance management systems, high-end content streaming and artificial scenario control.

To continue the highly valued discussion and knowledge exchange about VR training between LEAs, the consortium has set up a VR & Police Network. The mission of the network is to provide access to knowledge and future trends in VR (relevant to LEAs), bringing together different stakeholders and facilitating exchange and communication within this special interest group of VR and organising and providing access to special events and workshops to experience actual and future possibilities of VR. A request to join the network can be placed on the website: https://www.vrandpolice.eu.

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Appendix A: Worksheets for LEAs

System Acquisition Checklist

The following checklist will support LEAs when comparing different VR solutions to ensure important points and requirements where considered. More detailed information to each topic can be found in the main part of the deliverable.

VR Training Solution Requirements Checklist

Training Goals

- ☐ Clear goals
- ☐ Key performance indicators (KPIs)
- ☐ Training area suitable for VR training

Hardware

- ☐ Full body suite or compact version
- ☐ VR headset
- ☐ Tracking
- ☐ Locomotion
- ☐ Spatial sound
- ☐ Graphics, animation and kinematics
- ☐ Non-Player Characters
- ☐ Role Player Characters
- ☐ Spatial sound
- ☐ Tangible interaction and devices
- ☐ Physical props
- ☐ Multisensory experience
- ☐ Multi-user and interaction modalities

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Software

- ☐ Virtual Environments
- ☐ Terrain Editor
- ☐ Scenario Editor
- ☐ Live Scenario Editor
- ☐ Performance Monitoring: In-Action
- ☐ Performance Monitoring: After-Action
- ☐ Stress level assessment and manipulation

Facilities, Infrastructure and Human Resources

- ☐ Training facilities (e.g. space, power, light)
- ☐ IT infrastructure
- ☐ Data storage and protection
- ☐ Human Resources

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List of Measurements / KPIs

	Group of KPI	Name of KPI	Value	Calculation/measurement	Individual / Team	notes
1	Shots fired/weapon discharged	Shots close to danger (perpetrator -> trainee)	number	How many shots have been discharged by the perpetrator close to danger (i.e., how often is the distance < Z to line of fire from perpetrator to trainee X undershot)? Z = 20 cm	IND	
2	Shots fired/weapon discharged	Shots close to danger (perpetrator -> trainee team)	number	How many shots have been discharged by the perpetrator close to danger	TEAM	
3	Shots fired/weapon discharged	Shots by officer	number	How many shots have been discharged by officer X	IND	
4	Shots fired/weapon discharged	Shots by team	number	How many shots have been discharged by all team members	TEAM	
5	Flagging/line of fire	Flagging (perpetrator -> trainee)	number	How often did the line of fire from the perpetrator cross trainee x? (how often was trainee x flagged by the perpetrator)	IND	
6	Flagging/line of fire	Flagging (officer -> team)	number	How often did the line of fire from trainee x cross their own team (including trainee x)	IND	
7	Flagging/line of fire	Flagging (officer -> third party)	number	How often did the line of fire from trainee x cross any third parties?	IND	

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8	Flagging/line of fire	Flagging: (officer -> perpetrator)	number	How often did the line of fire from trainee x cross any perpetrators?	IND	
9	Field of Vision (FOV)	Covering 360°	percentage	How much (in %) of 360° is officer X covering via their FOV?	IND	
10	Field of Vision (FOV)	Covering 360°	percentage	How much (in %) of 360° is the team covering via their FOV?	TEAM	Group size usually of 2 or 4; preferably, trainers would like to have it calculated for the smaller group as well; e.g. if a 4 member team splits up into two 2-person teams to secure a building -> not yet implemented in REL system
11	Tactical movement	sighted by perpetrator	percentage	How much of trainee x's body surface is visible to the perpetrator?	IND	Not yet implemented in the VR system
12	Tactical movement	sighted by perpetrator	percentage	How much of the team's body surface is visible to the perpetrator?	TEAM	Not yet implemented in the VR system

Table 12: Key Performance indicators required by LEAs

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Performance Monitoring Requirements Checklists

During Training	Must have	Nice to have	Not required
Trainer can see physiological data during training	X		
Trainer can communicate with trainees	X		
Line of gun visible for trainer (not trainees)	X		
System reaction when gunline is in crossfire		X	
Trainer can be present within VR scenario	X		
Trainer can point where trainee should stand		X	
Trainer can pause during scenario	X		
Colleagues can watch exercise		X	
Physical impulse after critical mistakes		X	

After Training/Debrief	Must have	Nice to have	Not required
Playback, pause, rewind options	X		
Selecting which metrics to show		X	
Physiological measures report	X		
Different viewpoints	X		
Show alternative decisions			X
Feedback on avatar behavior			X

Table 13: Requirements example for In-Action and After Action Performance Monitoring

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LEA feedback questionnaire

1. How would you rate the overall quality of your experience with the VR system?

Excellent	Good	Fair	Poor	Bad
☐	☐	☐	☐	☐

2. Did you have any problems using the system? Yes ☐ No ☐

3. If yes, please describe them:

4. What was positive and worked well?

5. What was negative and did‘nt work well?

6. What are your ideas to make the system better?

7. I am… ☐**Trainer** ☐**Officer** ☐**others, namely: _______________**

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I am… ☐ **female** ☐ **male** ☐ **don't want to tell**

I am… **___ years old**

I am since… **___ years a police officer (____ years of it as a trainer)**

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7. Please, tick the box on this 5-level scale which is most appropriate	Not at all				Absolutely
I feel the system is easy to use.					
Learning how to operate the system is easy for me.					
I feel immersed in the 3D simulation system.					
I can move naturally in the VR simulation.					
In the virtual environment I can easily and well orient myself.					
I think virtual trainings are a useful addition to the other police trainings.					
The virtual environment offers better training opportunities than real training.					
I think the virtual environment is a useful training tool for police.					
I am willing to use the system in my future trainings.					
In VR trainings, I can learn things that I can later use in operations.					
I think after such a training I can better cope with similar situations in practice.					
I find the virtual environment helps me to realistically experience my own vulnerability and that of others.					
I think the virtual environment helps me to better understand critical operations.					
People (civilians, perpetrators, bystanders etc.) in the VR behave realistic.					
The virtual environment creates a realistic training scenario.					
In VR I can realistically handle objects (e.g. weapons, pepper spray, etc.).					

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