European Commission, Horizon 2020

# D4.5 Real-Time Training Progress Assessment Tool

SHOTPROS

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| Deliverable | D4.5 |
| Deliverable Lead | AIT |
| Related work package | WP4 |
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| Dissemination level | PUBLIC |
| Due submission date | 31.08.2021 |
| Actual submission | 31.08.2021 |
| Project number | 833672 |
| Instrument | RIA |
| Start date of project | 01.05.2019 |
| Duration | 42 months |
| Version log | V1.0 |

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# Versions

| Vers. | Date | Author | Description |
|---|---|---|---|
| V0.1 | 16/06/21 | Helmut Schrom-Feiertag (AIT) | First draft of ideas and concept |
| V0.2 | 4/07/21 | Helmut Schrom-Feiertag (AIT)<br>Olivia Zechner (AIT) | Structure & chapter assignment & additional content |
| V0.3 | 13/08/21 | Helmut Schrom-Feiertag (AIT)<br>Markus Murtinger (USE)<br>Olivia Zechner (AIT)<br>Jakob Uhl (AIT)<br>Nguyen Huu-Quynh-Huong (AIT) | Detailed tool description, stress assessment method, empirical study for stress cue evaluation, co-creation, use in training |
| V0.4 | 16/08/21 | Berend Kemperman (RL)<br>Birgit Harthum (USE)<br>Vana Hutter (VUA) | Review by partners |
| V0.5 | 25/08/21 | Helmut Schrom-Feiertag (AIT)<br>Jakob Uhl (AIT) | Incorporating comments and feedback from partners |
| V0.6 | 27/08/21 | Markus Murtinger (USE)<br>Birgit Harthum (USE) | Quality assurance and content check |
| V1.0 | 30/08/21 | Valerie Schlagenhaufen (USE)<br>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 |
| LEAs | Law Enforcement Agencies |
| NPC | Non-Player Character |
| RAT | Risk Assessment Tool |
| RR | Respiration Rate |
| RTTPAT | Real-Time Training Progress Assessment Tool |
| RVTD | Real-Time Trainer Dashboard |
| VR | Virtual Reality |

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# Table of Figures



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# Tables



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# 1 Executive Summary

This SHOTPROS deliverable 4.5 "*Real-Time Training Progress Assessment Tool*" focuses on the **real-time information**, **visualisation** and **control options** during a Virtual Reality (VR) police training session. Whereby three different groups using this control could be distinguished:

(a) the VR trainers,
(b) the VR system operators, and
(c) possible observers of a training session.

However, the focus regarding the developed functions is on the VR police trainers, as they are the most relevant user group of the new system. Therefore, the features developed and presented are very much related to the role of the VR trainer and support him/her in future work with the VR system and enables him/her with additional tools in his/her role as a trainer.

This deliverable summarises the created output of the conducted Human Factor (HF) studies and experiments (see D6.1) and builds on these findings. Based on the uncovered results and insights, innovative concepts (such as the stress-cue concept, see D4.1) were developed together with the law enforcement agency (LEA) partners. These concepts are applied in the current SHOTPROS VR system and implemented as part of the agile development process and technical releases (see D1.1).

Central questions for the creation phase were "what information or parameters do the trainers need for a real-time analysis of the training session?", "how can the trainers manipulate stressors directly or apply them in real-time in VR?" and "how can the current stress level of the trainees be calculated and visualised?".

Building on these questions, the created tool includes the following four key functions for the police trainer of a VR training session within the SHOTPROS VR system:

- *Live VR View*
- Trainee *Stress Level Assessment*
- *Stress Cue Control* panel
- *In-Action Monitoring*

For each of these four functions, the corresponding flows, interaction concepts and screen designs were developed in the course of the work for this deliverable. These developments were created in iterative feedback loops with the LEAs and new findings were implemented iteratively (see D1.1 for the agile process and iterative end user feedback).

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The identified and created features were developed based on the conceptual human factors model for Decision Making and Acting under Stress and in High-Risk Situations (DMA-SR) (see D3.2) and in close coordination with D3.3 “European Framework for Training and Assessment of DMA-SR Behaviour of Professionals”. The requirements workshops with our end user partners (see D2.2) and the different End User FeedbackWeeks (see 6.1) executed with LEA partners built a further base for this deliverable. These key functions follow the VR training guidelines and support the trainer in the VR sessions with the developed SHOTPROS VR system.

To better market and communicate these four new core features, the name "**Real-Time VR Trainer Dashboard**" was created. This dashboard connects the four functions on a clear visualisation during the VR training sessions and is therefore the central information and control element for the trainers. The dashboard is an interactive tool to observe VR training sessions from the **trainer perspective**, to personalise training session according to individuals’ training skills and needs in relation to the SHOTPROS stress topic and to measure live performance with real-time key performance indicators (KPIs). The term "Real-Time VR Trainer Dashboard" will be used in this and future deliverables as well as in the final developed SHOTPROS VR solution.

All findings from this deliverable are applied to the actual technical requirements for the SHOTPROS VR system (collected and reported in D4.6, M30), the agile product backlog and feeding directly into the development tasks of WP5. Results are closely related to deliverable D5.4 “VR Results Dashboard for Reviewing and Measuring Training Sessions Performance and Output for Evaluation and Field Trials” (M33) which focuses on the After-Action Review (AAR), i.e. the evaluation and analysis of the VR training at the end of a training session.

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# 2 Added Value

Deliverable 4.5 as part of the WP4 builds, together with WP2 and WP3 the base on the definitions and evaluations regarding the project and the future VR solution (WP5). The created solutions will then be validated during the field trials (WP7). It herby mainly contributes to defined SHOTPROS objective 2 “Virtual Reality (VR) Environment that allows to manipulate Human Factors in the Context of DMA-SR and observe related Behaviour”.

Objective 2 comprises a VR system, that is able to **dynamically introduce psychological** (such as a frightened child VR character within the scenario) **and physiological** (such as audio input, e.g. loud music, screaming persons, etc.) **cues** into virtual training scenarios. Throughout this development a large range of cues was and will be further scientifically assessed, for their ability to induce certain emotions and after a pre-selection implemented into the SHOTPROS VR training system to train appropriate behaviour during VR training sessions. These goals have now been achieved through the development of the four key functions in the tool (*Live VR View*, Trainee *Stress Level Assessment*, *Stress Cue Control Panel* and *In-Action Monitoring*).

In the Humans Factor (HF) studies and experiments (see D6.1) conducted together with the LEAs, the functions already could be evaluated in several development phases. The end users found them to be very helpful and valuable for future VR training and highly innovative in comparison to existing VR solutions on the market.

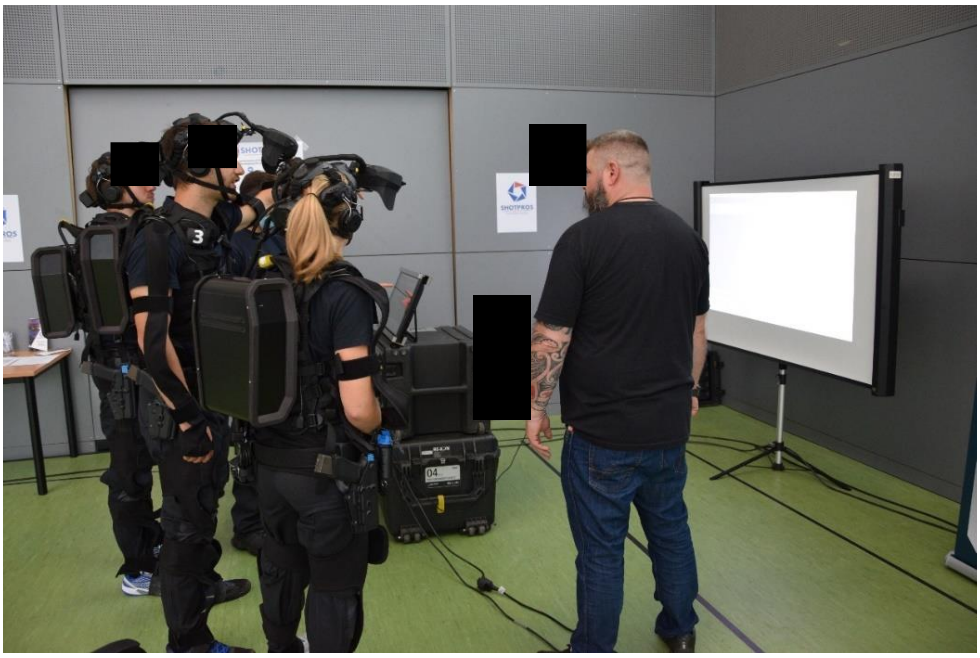

*Figure 1: Evaluation of the core features during the HF study in Selm (Germany) with 4 police trainees and one experienced police trainer.*

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# 3 Introduction

The developed tool is an innovative and interactive tool to observe VR training sessions from the **trainer perspective**, to personalise training session according to individuals' training skills and needs in relation to the SHOTPROS stress topic and to measure live performance with real-time key performance indicators (KPIs).

Through these novel interaction options and real-time measurements, police trainers have the possibility to make ad-hoc adjustments to the VR training sessions (e.g. activate or deactivate one or more stress cue(s) depending on the trainee's current state and performance, displayed in the created dashboard) and herby directly steer the training from their perspective without interruption or other "out of the scenario/unnatural" actions.

To validate and rate the most import stress cues, identified by LEAs in D4.1, a scientific HF study (see D6.1) was conducted, measuring physiological as well as psychological responses in a virtual environment to each stress cue.

Finally, a prototype interface was designed and evaluated by partners and LEAs and implemented into the actual SHOTPROS VR system according to the agile development process (see D1.1).

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 | Factors influencing human decision making and acting in stressful situations and relevant stress cues identified in the requirement phase. |
| **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. |
| **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 relevant parts to be changed in a scenario. |
| **D3.2** | Conceptual Model of DMA-SR Behaviour and a Research Agenda to validate the Conceptual Model | Definition of stress, triggers, and stimuli. Stress cues are audio-visual stimuli that are used to evoke stress reactions in trainees. |

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| **D3.3** | European Framework for Training and Assessment of DMA-SR Behaviour of Professionals | Provides an extensive evidence-based set of recommendations for implementing VR DMA-SR training in current police curricula. Especially because of the physiological measurements, the ethical, safety and privacy issues discussed 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. |
| **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 |

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

The created outputs and solutions from this deliverable will strongly impact the following future deliverables:

| No. | Title | Basis for |
|---|---|---|
| **D4.6** | Create Technical Requirements for VR Training Scenarios | Real-Time Training Progress Assessment Tool has to be considered in the requirements document for the development |
| **D5.1** | VR System Design Document for development of SHOTPROS VR Environment for conducting the Human Factor Studies (WP6) and the Field Trials (WP7) | Real-Time Training Progress Assessment Tool has to be considered in the design document for the development. |
| **D5.2** | Agile Development of VR Test Scenarios & Environment and Preparation & Provisioning of Infrastructure for conducting the Human Factor Studies (WP6) | The training progress assessment tool will be implemented into the BLUESUIT system during the agile development of the scenarios for the human factor studies. |
| **D5.3** | Created VR Scenarios for DMA-SR Training for Evaluation and Field Trials (WP7) | The training progress assessment tool will be demonstrated in the field trials. |
| **D5.4** | VR Results Dashboard for Reviewing and Measuring Training Sessions Performance and Output for Evaluation and Field Trials (WP7) | The most effective stress cues will be included in the final VR training scenarios, based on the results of the HF Studies and selection in the agile development process. |

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

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## 3.1 Relevant Wordings in the Context of SHOTPROS´ VR System

In the following table, relevant wordings are defined to better understand the contexts, functions and approaches in the further course of the deliverable. These wordings were also defined during the work for D4.5 and will also be implemented and used in future deliverables and in the future VR demonstrators and screen design. Furthermore, the wordings were also defined from an exploitation and marketing perspective.

| Term | Description |
|---|---|
| Real-Time Training Progress Assessment Tool (RTTPAT) | This tool is an extension of the exercise control and spectator view of the SHOTPROS system for the VR training and provides a set of user interfaces and real-time interaction possibilities to monitor the progress of a VR training from different freely selectable perspectives, keep track on training performance indicators, asses the stress level of the trainees and the option to easily modify the scenario by controlling stressors. This tool is visualised on a separate large (touch) screen next to the training field for the trainer and possible spectators to monitor the training within the VR visualisation and steer the course of the scenarios. Also see figure 2 in this document. |
| *Live VR View* | Main display element to clearly show the current action in the VR session to the trainer and offers the possibility to choose between different static and dynamic views. It shows two visualisations, a top view in the left part and a free adjustable view on the right. This could be the field of view of the individual trainees, an overview perspective, a view from the perpetrator's perspective, and the option to move the camera freely. The trainees in the view are additionally marked with symbols in both views indicating position and stress level. |
| *Stress Level Assessment* | The stress level of the trainees is assessed by bio-signal measurements and determined through analysis of HR, HRV and BR. The stress level for trainees is shown in the user interface by symbols and a colour code: green for normal, yellow for increased, orange for high and red for very high stress. The stress level is also shown in the *Live VR View* by symbols and colour codes at the position of the trainees. |
| *Stress Cue Control* | The *Stress Cue Control* (SCC) panel allows stress cues to be activated and deactivated instantly during training. Scenarios can also have numerous stress cues that cannot |

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| | be activated via the control panel and whose triggering is automated via temporal or spatial triggers. Which stress cues are intended for the control panel for interactive activation is defined during the scenario creation in coordination with the trainer and shown in the panel. |
| *In-Action Monitoring* | The *In-Action Monitoring (IAM)* panel can be expanded from the right side of the window and gives trainers and spectators an overview of the trainees' as well as the group's performance based on selected KPIs during the VR training setup. |

*Table 3: Relevant wordings in the context of SHOTPROS´ VR system*

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# 4 Challenges for an Innovative Police Training VR System

Virtual Reality (VR) training has become increasingly important for police first responders in recent years. Improving the training experience in complex and challenging contexts requires ecological validity of virtual training. To achieve this, VR systems need to be capable of simulating the complex experiences of police officers 'in the field.' Realistic situations have been shown to enhance the transfer of knowledge and performance under pressure (see D3.3). One way to do this is to add stressors into training simulations to induce the likelihood of stress similar to the stress experienced in real-life situations, particularly in situations where this is difficult (e.g., dangerous or resource-intensive) to achieve with traditional training.

To produce an ecologically valid VR training experience for police officers who have to regularly perform under stress and high-risk situations, stress needs to be flexibly inducible. This can be achieved by enhancing the VR training scenario with stressors that add complexity to the scenario and allow for personalised training sessions based on the trainees' learning goals, pace, needs, and time constraints (also see D3.3 - chapter 3 about variation and differentiation in VR trainings).

Based on the requirements and needs of the end users, the following questions were investigated in this deliverable:

(a) how known real-world stressors can be translated into audio-visual stress cues in VR training environments (based on the identified stressors described in D4.1).
(b) how trainers can use these stress cues to enhance and variate individual training experiences during the training session.
(c) how can the stress of the trainees be displayed and what information is necessary?
(d) which performance indicators are relevant for the trainer during a training session in real time?

Based on these central questions, the so-called "Real-Time VR Trainer Dashboard (RVTD)" was developed in the course of the deliverable.

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# 5 Real-Time VR Trainer Dashboard (RVTD)

The following chapter gives an overview of the goals of the novel developed "Real-Time VR Trainer Dashboard (RVTD)" as well as its core functions.

## 5.1 Objectives of the RVTD

The RVTD gives police trainers and spectators real-time information on trainee's stress level and performance as well as the opportunity to dynamically introduce psychological (e.g. stress inducing audio-visual cues) and physiological cues during the training session.

Building on the requirement workshops (D2.2), the conducted EndUser FeedbackWeeks (in Berlin and Selm) and other conducted human factor (HF) studies and experiments (see D6.1), the following objectives for the RVTD were defined:

- Measure and track training progress of trainee(s) in real-time (stress, performance)
    - current stress level based on physiological measurements (see chapter 5.2.2) and
    - performance of trainee based on pre-defined KPIs (see chapter 5.2.4)
- 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
- Help trainers and spectators to understand the relationship between stress- and anxiety-inducing factors and their impact on the DMA process

The created solution from this deliverable consists of the following four core functions as briefly described below: (Note: the background and creation steps of these four core functions are described in more detail in the following chapters.)

- *Live VR View*: Central element to make the current events in the VR training session visible to the trainer and the possibility to display different VR views (including from each trainees' point of view, meta view, display from the perpetrator's perspective, etc.).
- Trainee *Stress Level Assessment*: Representation and visualisation of the estimated stress level in real-time of each actively participating trainee within the current training session. This stress level is calculated for each trainee based on information from physiological measurements (see D4.3).
- *Stress Control Panel:* Management and control of stress cues within a VR training session, such as activating or deactivating a screaming of a person or a barking dog.

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- *In-Action Monitoring*: Efficient display of relevant KPIs for trainers to track the performance of trainees in the current training session and to support the defined learning objectives (e.g. distances between trainees and perpetrators, usage of police equipment, line of fire, etc.).

The RVTD is available for two different user groups: a) trainer and b) system operator. The RVTD supports both groups with the same functions for *Stress Level Assessment*, *Stress Control* panel and *In-Action Monitoring*, only they are integrated in the two different components of the training system, a) the trainer view and b) the exercise control:

**Ad a) Trainer view:**

Provides the *Live VR View* with a wide variety of possible perspectives to observe the training session. This station is mainly used by the trainer during the session to monitor the trainees (changing perspectives, setting bookmarks for detailed discussions after the training etc.) and to steer the training (changing the stress induction, communicating as dispatcher, giving commands if necessary, etc.). Invited spectators (such as other trainers or trainees that are not in the session) can join at this station. In this case, model learning (see D3.3) is the applied concept - Learning from the model of others doing the training has a learning effect on spectating trainees.


*Figure 2: Structure and system for the VR trainer as well as possibility for spectators on the larger screen.*

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**Ad b) Exercise control for the system operator:**

Also provides a *Live VR View, but* with the full range of scenario manipulation options. Compared to the touchscreen interface on the trainer/ spectator station described above, the keyboard and mouse setup allows for more complex actions (Figure 2), such as adding and removing objects, NPCs including motion trajectory and behaviour, changing appearance, triggering events, etc. (Figure 4). Besides assisting the trainer control the scenario during the exercise other task interfaces are available, e.g. system setup and configuration, registration of trainees and gear assignment. (The details of the exercise control will be described in D4.6 and D5.1)

*Figure 3: View and working place of the system operator at the exercise control station.*

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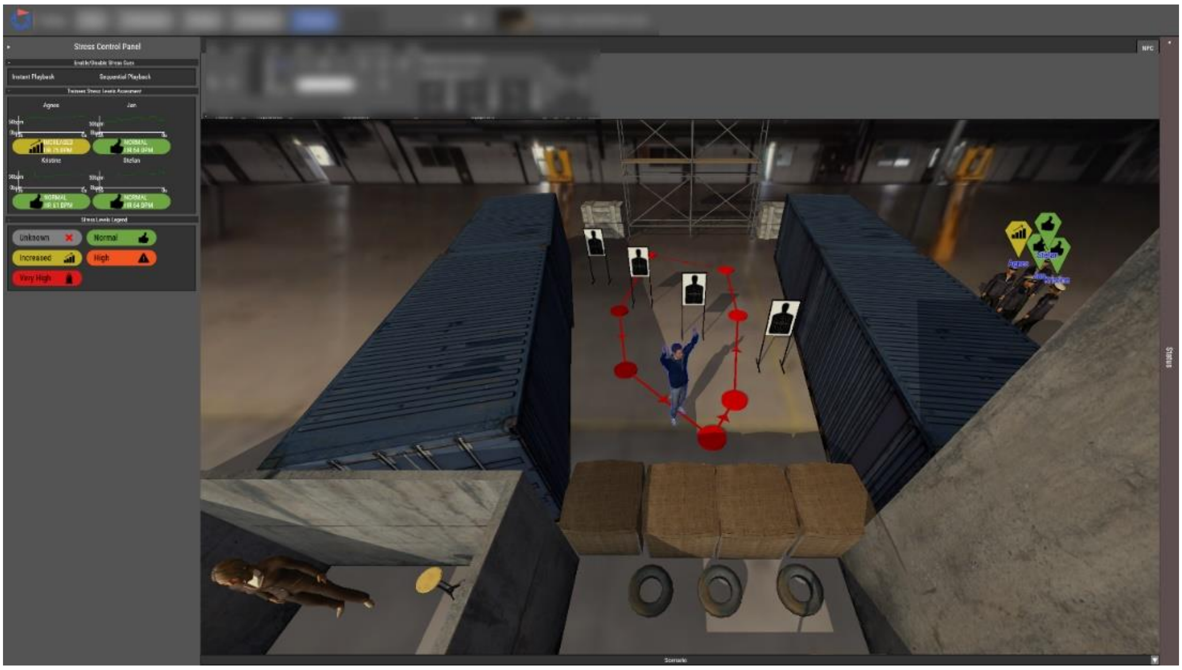


*Figure 4: System operator interface when a "show me your hands" command was given to a Non-Player Character (NPC) walking along a path.*

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## 5.2 Concept and Design of the RVTD

The following Figure 5 shows the new trainer user interface with the visual arrangement of the **four core functions** consisting of the *Live VR View* (1) as central element and to the right the part of the trainer dashboard with performance and stress assessment. Over tabs the trainer can switch between the *Stress Cue Control (2)*, *Stress Level Assessment (3)*, tab and the performance monitoring tab with the *In-Action Monitoring (4)*. This dashboard area can be expanded horizontally, and each panel can be folded in and out vertically on the tab.

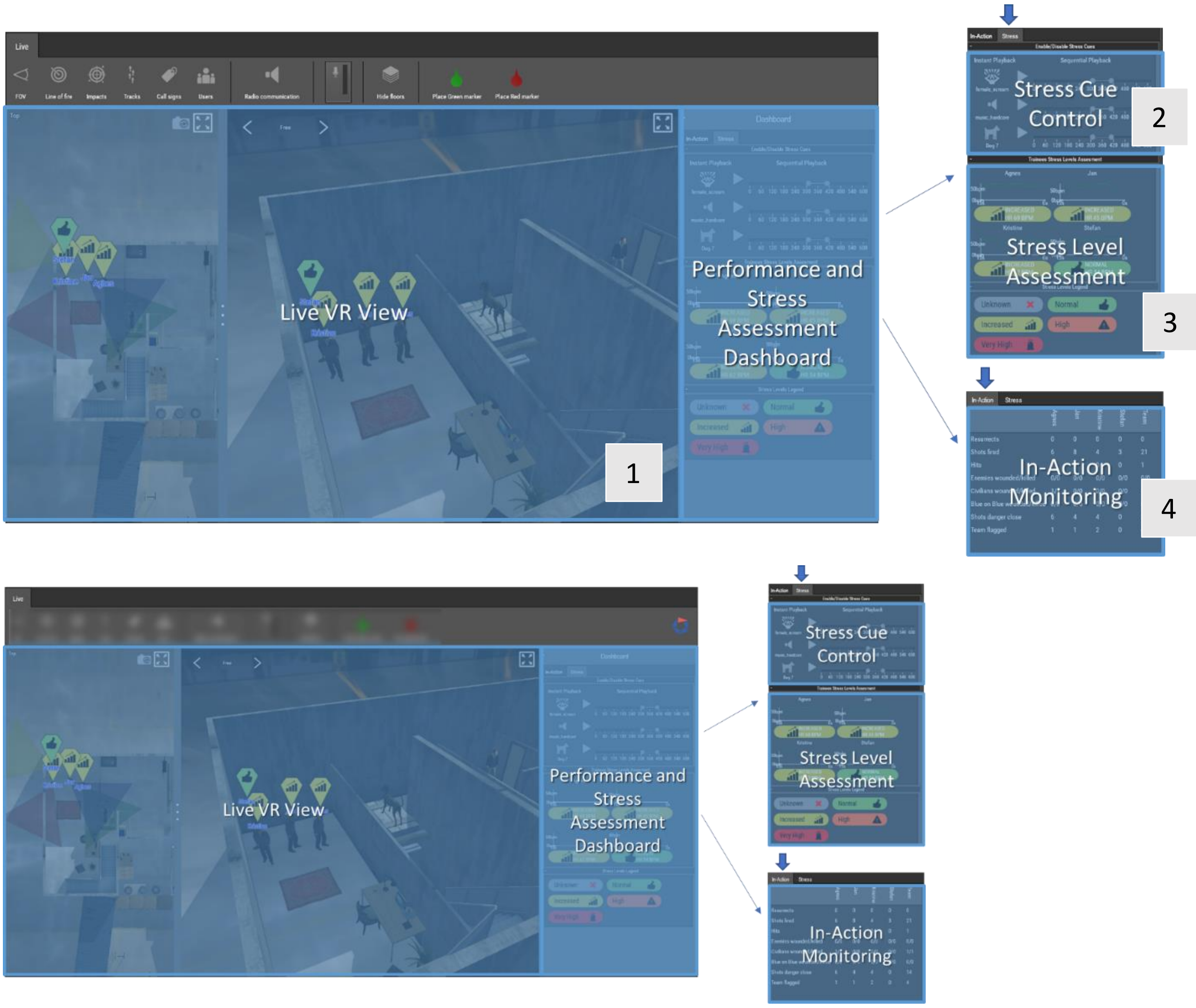


*Figure 5: User interface for the trainer to support the real-time training progress assessment.*

In the following section the user interfaces of the individual areas are presented, and their functionality is explained in detail.

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### 5.2.1 Live VR View

The *Live VR View* is the central part of the RVTD, showing the actual VR scenario and the real-time location of trainees within the scenario. The trainer has the possibility to view the scenario from several different perspectives (top view, from the view of each person, over the shoulder of a person, completely free cam view, etc.) and zoom in or out of scenarios and buildings.

For a simple and pleasant user experience when using the Live VR View, a hardware game controller was implemented. As shown in Figure 6, with this controller, the VR trainers can quickly change views and freely move the camera position. This feature was rated very positively during the EndUser FeedbackWeeks (see D6.1), as it allows a quick perspective selection and interaction for the trainers. For detailed settings or selections, interaction can be done via a touch screen.


*Figure 6: Usage of the Live VR View via a hardware game controller, during a training session and analysing the real-time action.*

Furthermore, a live indication of the estimated stress level of each trainee is indicated in real-time via a coloured shape with an icon. The icon is displayed above the virtual trainees and indicates one of four different statuses:

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(a) green indication with the thumbs up icon means normal conditions,

(b) yellow with increase icon for increased stress,

(c) orange and the triangle for high stress and

(d) red and the alarm icon a very high and already dangerous level.

This efficient visualisation enables the VR police trainer to assess a quick check of each trainee and to better understand the real-time status of the team. The icons in the *Live VR View* not only mark the status but also show where the trainees are positioned within the actual VR scenario (Figure 7). Since only the trainees that are visible in the respective perspective, e.g. because you zoomed in to a certain room where only 2 of 3 trainees are located are displayed here, there is an overall display of all trainees in a list in the *Stress Level Assessment* panel on the right side to always have the complete overview on the stress assessment. The dashboard on the right side of the *Live VR View* contains the *Stress Cue Control* panel and Trainee *Stress Level Assessment* as described above.

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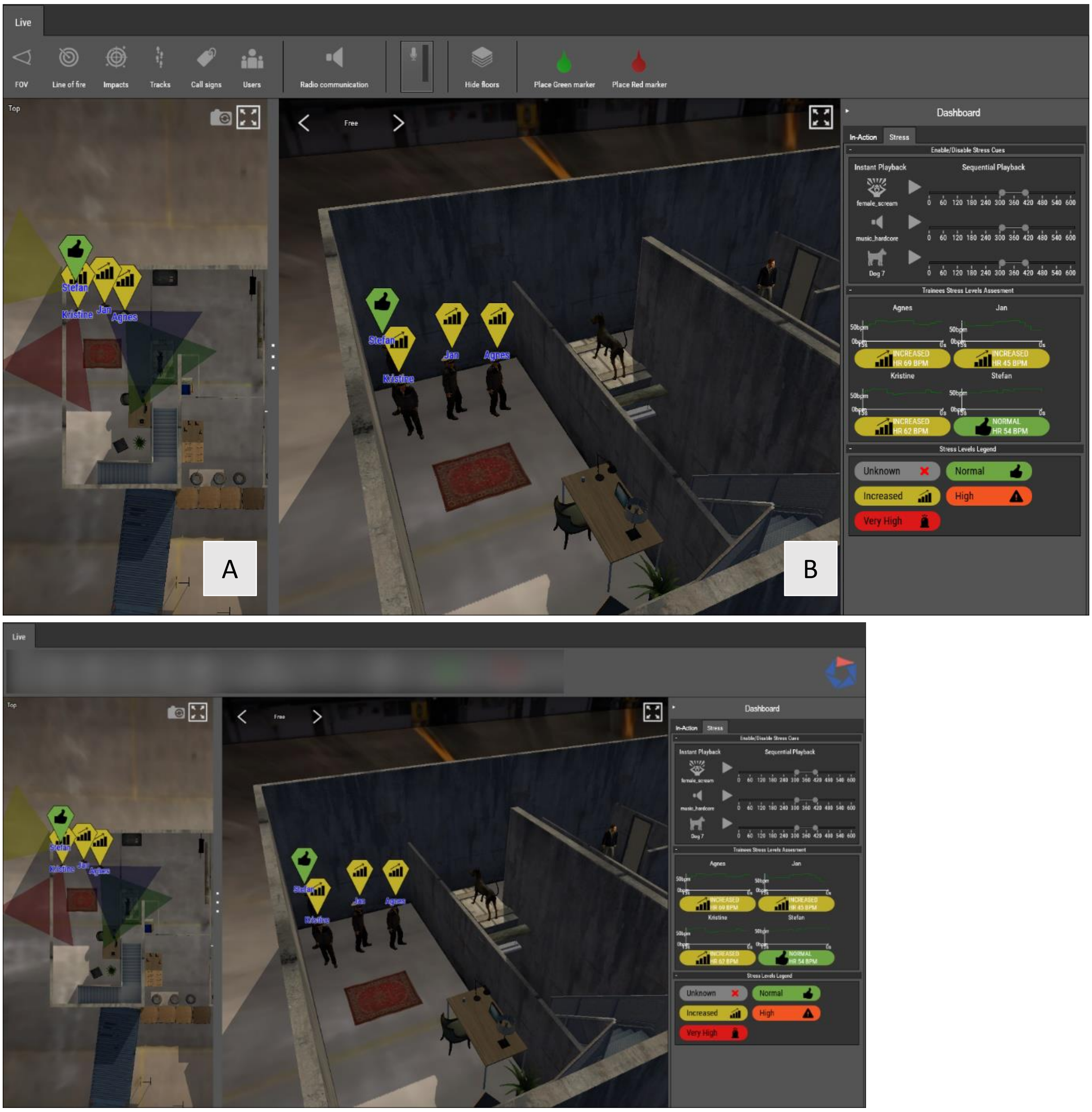


*Figure 7: Live VR View of a training with 4 trainees.*

The *Live VR View* itself is divided horizontally into two areas, the left (A) and the right viewport (B) (Figure 8):

**Left viewport (A)**

In the left viewport the trainer/spectator can follow the action always in a top down view. The view can be moved (left-right-up-down) and zoomed (in-out) to focus on interesting areas. With the re-centre button the view can be reset (on all the trainees/ NPCs). With the expand button the view can be made full screen.

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**Right viewport (B)**

In the right viewport the trainer/ spectator can choose several camera perspectives. The default free camera can be controlled with an easy to use game controller to move around freely in the scenario. The other options follow the perspective according to which object is selected. These are:

- Eye: Follows the perspective of a trainee. This allows the trainer to see what the trainee is seeing
- Shoulder: Also follows a trainee but from a perspective slightly behind the shoulder of the trainee (Figure 9)
- Orbit: Similar to the shoulder perspective but allows the camera to be rotated around the trainee
- Weapon: Follows a perspective along the line of fire of the trainee. This is only available when the trainee is wielding a weapon.
- Eye (NPC): Same as Eye, but following an NPC
- Shoulder (NPC): Same as Shoulder, but following an NPC (Figure 10)
- Camera: Switches the perspective to a predefined camera viewpoint (setup during scenario creation).

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*Figure 8: Left and right viewport, including re-centre button (left & right viewport) and camera choices (right viewport – drop-down). Instead of the drop-down to directly select a perspective, the arrow buttons on the left and right support cycling through the perspectives.*

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*Figure 9: Follow trainee shoulder view.*

In the Shoulder following mode, the same concept as before is applied as choosing the camera perspective: the drop-down lets the trainer choose the trainee to follow directly, while the arrow buttons cycle through the trainees.

*Figure 10: Full screen perspective from the NPC shoulder. Note there is a “Restore normal view” button to go back to split screen mode.*

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### 5.2.2 Trainees Stress Level Assessment

The Trainees *Stress Level Assessment* panel shows trainees current stress level of each trainee during the VR session. The stress level is based on the one hand on heart rate variability (HRV) which is a recognised indicator of stress (Kim u. a. 2018) and combined with heart rate (HR) and respiration rate (RR). For a simple and quick overview of the current status, the stress level was divided into 4 categories (a detailed formula and derivation of the values as well the categories is explained in chapter 7.1.1 and in the Annex.

1. Normal
2. Increased
3. High
4. Very High

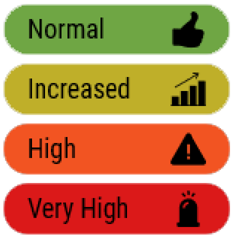


*Table 4: The four stress levels used for Stress Level Assessment*

The four levels are presented as kind of "traffic light" where each level is accompanied by an icon. The colours ranging from green with a thumb up sign for normal level (no stress) over yellow with a rising bar chart for increased stress level, orange with a warning triangle for high and red with an alarm signal for a very high and dangerous stress level.

To measure the necessary physiological signals (defined in D4.3), the Zephyr™ BioHarness™ sensor and belt is used as it provides reliable and valid measurements of heart rate (Nazari et al 2018) and respiration rate. The obtained bio signals are processed and the results for the stress levels are visualised on the screen at the *Stress Level Assessment* Panel as well in the *Live VR View*.

In the user interface all levels are displayed in a legend for explanation. The colour grey and the cross symbol is shown if no data is available for a trainee. In addition, above the stress levels indicators for the trainees also the heart rate is shown in a time diagram. The legend as well as the level assessment can be collapsed.

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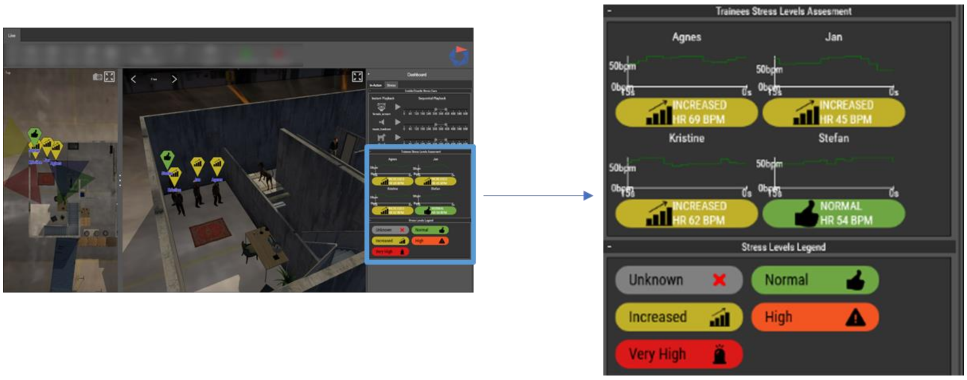


*Figure 11: Visualisation of Trainees Stress Level Assessment.*

### 5.2.3 Stress Cue Control

The *Stress Cue Control* panel 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).

The end user requirements (D2.2) and EndUser FeedbackWeeks (D6.1) revealed 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.

Stress cues are activated with the intention to induce immediate stress in trainees at any time individually by single play buttons for instant playback or with additional selection of the start and end on the timeline. Simultaneous playback of all stress cues is possible by pressing all play buttons in quick succession. But as training should induce stress cues step by step (and the reaction on them being supervised to provide "achievable goals for the trainees – see D3.3) we didn't offer a "play all" option.  After pressing the play button, the icon changes into the stop button and the stress cue can be stopped by pressing the button again, were the button changes back to the play shape.

Besides activating stress cues in the *Stress Cue Control,* they can also be activated by spatial trigger zones, e.g. when a trainee enters a room or time-controlled after a period of time with a fixed duration. These properties can be defined already during the scenario creation. If a stressor is triggered by one of the events, this is also displayed in the *Stress Cue Control* where the play button changes to a stop button and the stress cue can be stopped by the trainer.

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*Figure 12: Stress Cue Control*

In D4.1 a stress cue repository was defined together with the LEAs and these stress cues were ranked by them according to stress factor from their point of view. The stress cues were then implemented as audio-visual cues in VR and assessed about their ability to induce stress to police trainees (see D6.1, HFWeek2). This validation is described in detail in Annex.

Out of this repository suitable stress cues can be selected for usage in the Stress Cue Control during the VR training scenario definition. In Figure 12, for example, these are a female scream, loud music and a barking dog.

During the EndUser FeedbackWeeks (D6.1) it was mentioned a few times that it could help to have a "where is the stressor" button. This means that the trainer (if not sure where the shown stress cue will come from) clicks this button and the right view panel is zoomed in to the source of the stress cue. If the trainer clicks for example on the "where is the stressor" button next to the barking dog, the screen centers to the position of the barking dog in the correct room. Afterward the trainer can click to get back to the view where he/she started from. This feature will be implemented in one of the next release cycles of the agile development plan.

### 5.2.4 In-Action Monitoring

The *In-Action Monitoring* panel can be expanded horizontally from the right side and gives trainers and spectators an overview of the trainees' performance (individually and also on group level where suitable) based on selected KPIs during the VR training setup. This feature was developed in close cooperation with all LEAs (see D6.1 with special focus on the EndUser FeedbackWeeks 1-3). Experienced police trainers indicated the most relevant KPIs for a better understanding of the real-time situation and to quickly interpret the actual trainings performance. In chapter 7.3 the development of the KPIs for training with the VR system is described in detail.

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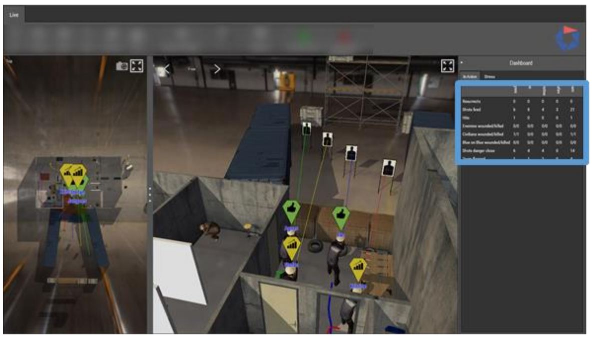

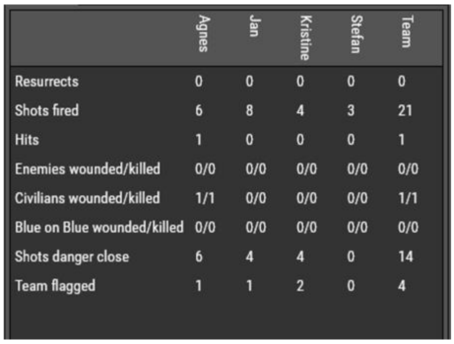

| | Agnes | Jan | Kristine | Stefan | Team |
|---|---|---|---|---|---|
| Resurrects | 0 | 0 | 0 | 0 | 0 |
| Shots fired | 6 | 8 | 4 | 3 | 21 |
| Hits | 1 | 0 | 0 | 0 | 1 |
| Enemies wounded/killed | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| Civilians wounded/killed | 1/1 | 0/0 | 0/0 | 0/0 | 1/1 |
| Blue on Blue 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 13: In-Action Monitoring showing the selected KPIs per trainee and as team*

# 6 Use of the RVTD in Training

In the following chapter a typical training session within the SHOTPROS VR training system will be described in a step-by-step walk-through. The training framework is based on the defined guidelines and insights from D3.3 and transferred into the technical VR solution.

**Step 1: Preparations for training and data input**

Before you start a VR training session, you first have to define the essential training parameters and framework conditions. This is done in a wizard (a step-by-step process) to assess a suitable level of stress and complexity that aligns the training objectives. After the definition of the training framework, the scenario parameters and occurring events of a scenario, the next step is the selection of possible stress cues that will be available for the Stress Cue Control in the training. In the following Figure 14 and Figure 15 visual concepts of the setup wizard are shown. The concept and the used parameters for the wizard are based on the created Risk Assessment Tool (RAT) from the D4.7.). These created outcomes were transferred to the wizard and support the trainers so setup a training session.

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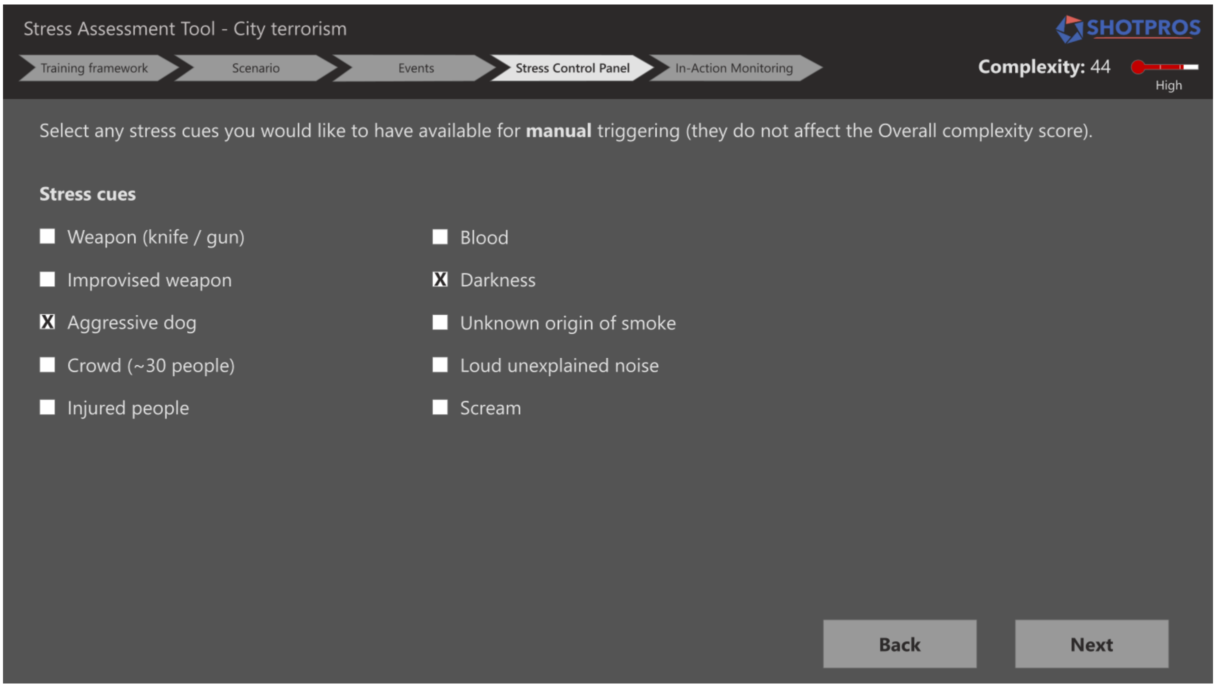


*Figure 14: Stress cue selection for the used stress cues in the Stress Control Panel during the scenario training (visual concept of a setup wizard).*

In the next step the selection of the KPIs that the trainer wants to track during the training can be chosen in the wizard, shown in Figure 15 as a visual concept. To keep the complexity for the VR trainer low, a maximum of 5 KPIs can be selected for display here.

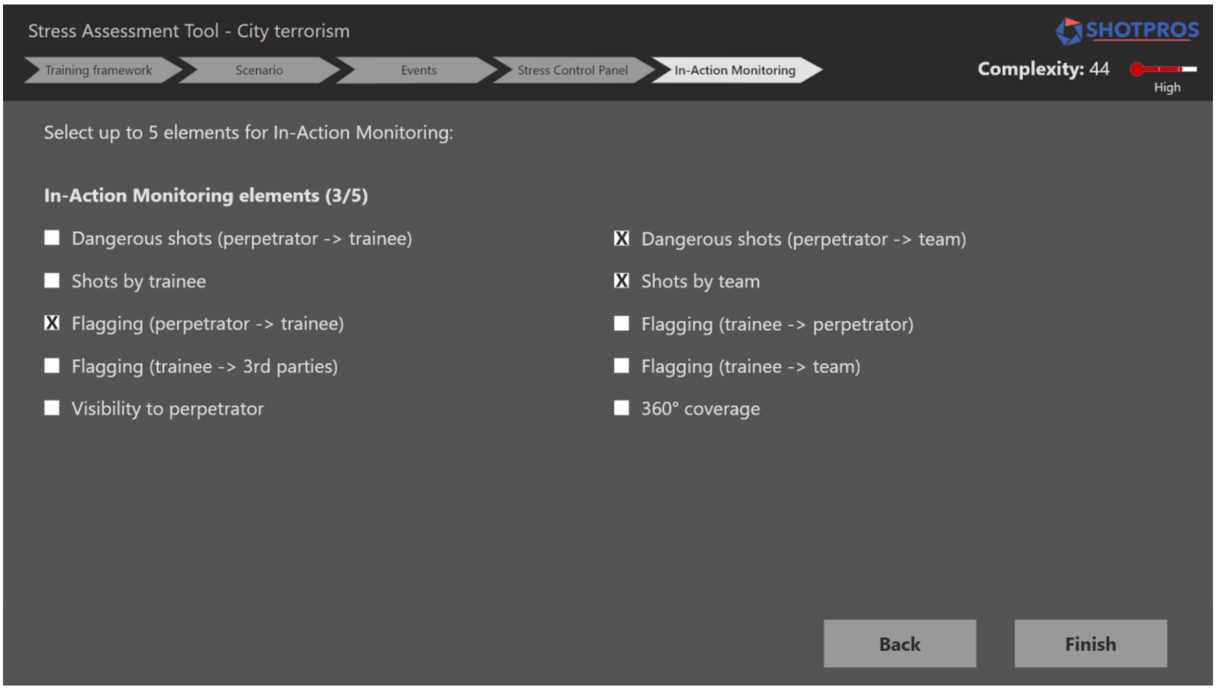


*Figure 15: KPI selection for the In-Action Monitoring of the training (visual concept).*

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When the scenario setup is finished and the training scenario has been created according to the setup, the system is ready for the training execution.

**Step 2: VR Suits, VR equipment & Zephyr™ BioHarness™ (chest strap)**

As part of putting on the SHOTPROS VR suit and equipment (in D5.1 the entire VR equipment is described, including smart vest, head mounted display, tactical belt, etc.) trainees will also strap the Zephyr™ BioHarness™ 3.0 sensor and belt around their chests, to collect bio signals necessary to calculate trainee's stress levels. The Zephyr™ BioModule™ Device on the belt needs to be turned on and connects itself (via Bluetooth connection) to the SHOTPROS VR system. The system operator links the number of the device with the trainees in the VR system to create a correct assignment. From this moment on, data can be sent back to the VR system and recorded.

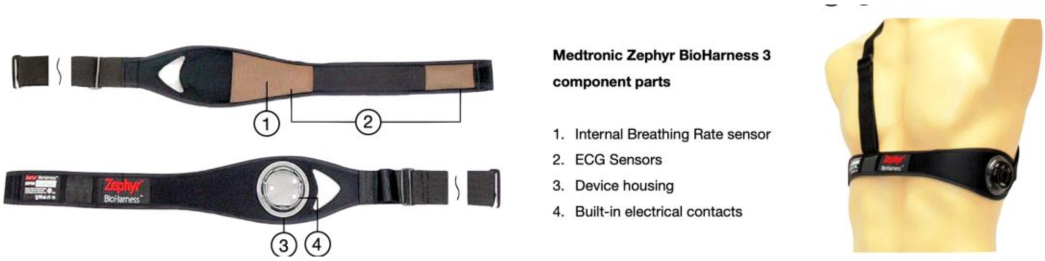


*Figure 16: Zephyr™ BioHarness™ 3.0 (property of Zephyr Technology Corporation, Annapolis, MD, USA—a division of Medtronic).*

The next step is putting on the VR headset and executing the calibration of the tracking system. Trainees will be guided through this process by a visualised tutorial.

**Step 3: Baseline recording for Stress Level Assessment**

To finalise the calibration and preparation phase for the trainee, a so-called stress level baseline recording needs to be done in a dedicated recording phase. Biological signals, such as heart rate, hart rate variability and respiration rate fluctuate amongst individuals based on their age, fitness level and daily constitution (Kim et al., 2018). Therefore, a physiological reference point of biological signals needs to be recorded.

To ensure trainees are relaxed and not distracted by their surroundings they are required to look straight ahead, relax and breath calmly for two minutes. During this time their headset will be muted so that they are not distracted by other trainees. Biological signals will be recorded with the Zephyr™ BioHarness™, which provides reliable and valid measurements of heart and respiration rate. The Zephyr™ Performance System was integrated as part of the agile development process into the VR SHOTPROS system (see D1.1 and D5.2) and the

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recorded data are stored within the system (Figure 17). The connection between the sensor and the VR system is established via a Bluetooth connection to the trainee client. The trainee client sends the data (together with other streams like motion and voice capture) to the server. The server calculates the estimated stress level based on the raw data and replicates the information to other clients to be visualised. The server also stores the data, on the one hand in proprietary format used for AAR, but also in open format for research purposes.

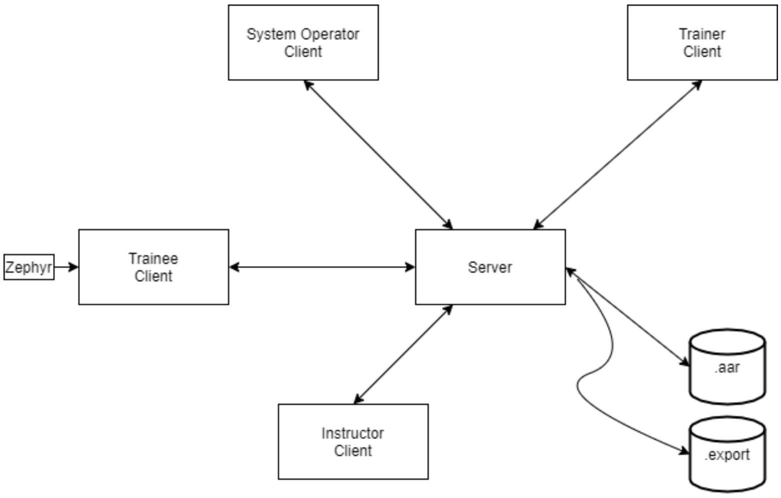


*Figure 17: System architecture showing the integration of the Zephyr™ BioHarness™*

Once the SHOTPROS VR System has a valid baseline recording, trainees will be marked with a green thumbs-up icon in the VR Live View (Figure 18). In case of no valid signal can be recorded the icon will stay grey with a red cross (Figure 19). From the operator view a re-calculation can be started for each person in the VR – then there is again no audio and no video input for this person to re-record a baseline measurement.

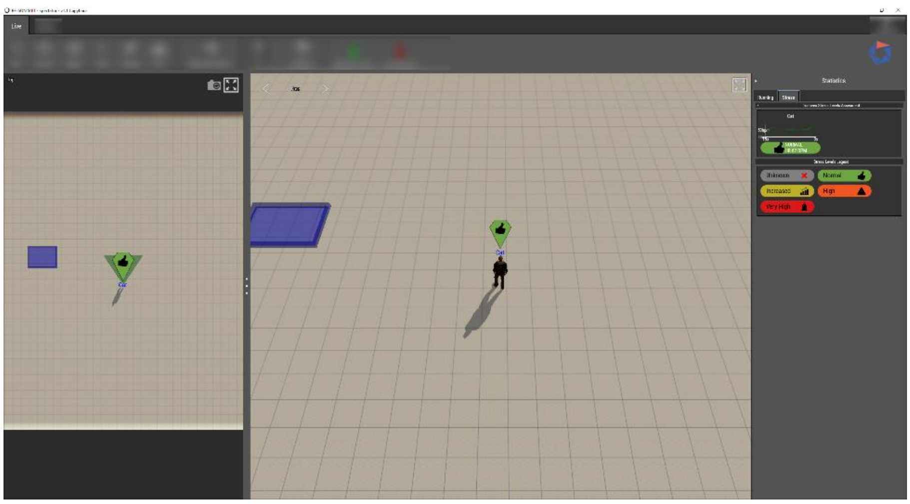

*Figure 18: Live VR View showing a trainee in the waiting room with stress level indicator as well in the real-time Stress Level Assessment panel at the right.*

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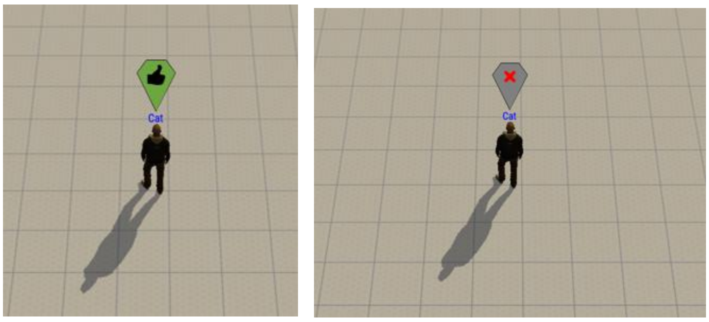


*Figure 19: Visual indication shown in the VR Live View: (left) if the baseline measurement was successful, (right) if no signal is available.*

**Step 4: Monitoring by trainer during the VR session**

Trainees are now able to act in the VR – typically they start with a tutorial training to get used to the VR itself and the available gear and the tactical belt. From now on, trainees will be monitored via the RVTD, which provides information on whereabouts, activities and stress levels of each trainee. If trainers notice that certain stress levels of trainees are already high, they have the possibility to deactivate certain stress cues and thereby reduce the perception of stressful events for the trainees. On the other hand, if trainer's believe trainees would benefit from additional stress cues, they have the possibility to add stress cues via the Stress Cue Control panel of the RVTD (Figure 12). A trainer now can monitor the whole training and adapt the scenario, objects or the reaction of avatars or role players accordingly to provide suitable variations. If necessary, in-between feedback can be applied or notes can be made (by setting bookmarks in the system) for the final review.

**Step 5: Overall training assessment in After-Action Review (AAR)**

All data recorded throughout the training session will be available in the *After-Action Review*. and can be assessed by the trainer by using different perspectives of the re-play, jumping to certain events in the timeline or reviewing the KPIs. Concerns should be raised here regarding the psychological safety of the training environment when personal data is displayed in the AAR. The presentation of any physiological data in the AAR must be clarified with the trainees in advance and their consent is required, especially if the AAR is carried out in groups. The created concepts and functions of the AAR will be reported in D5.4.

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# 7 Supporting Evidence and Justifications

The following chapter describes the approach to the creation and development the presented core RVTD functions, with a focus on the derivation of the stress cues to be implemented (based on the defined stress cues in D4.1) as well as the selection of the possible KPIs that can be displayed in the In-Action Monitoring. Furthermore, the implementation of the real-time stress measurement is explained, and the derivation of the calculation based on the conducted studies and their results are described. This chapter serves to better understand the previously described outcomes and to deepen the information.

## 7.1 Trainee Stress Level Assessment

### 7.1.1 Physiological Assessment Method

The physiological stress assessment method computes a stress level on the combination of the parameters of HR, HRV and RR. The combination will support a more reliable indication of the likelihood of acute stress in real-time which is necessary especially in such a dynamic environment, where changes have to be assessed quickly. A combined score for the stress assessment is computed using the change of these three parameters in relation to the baseline values and summarised in a weighted sum of these three values. These weights are determined by a multiple regression of the three parameters on the subjective stress ratings of the stressors by the trainees (see Annex). Some existing conceptualisations of stress detection (see Firstbeat Technologies Ltd., 2014) include a measure of physical activity, to differentiate between psychological stress and an altered metabolism caused e.g. by movement. As an outlook we plan to fine-tune our model of stress assessment with the activity score provided by the Zephyr™ BioHarness™ (which reflects the amount of movement in any direction), to assess its impact.

This assessment method will take 30 seconds intervals moving averages of the three variables and calculate the relative difference to the individual baseline. For each trainee a baseline measurement has to be done at the beginning of the VR training. This is done during the setup phase when the trainees are in the VR waiting room to record RtoR values (the time between heartbeats also called R-R interval) and respiration rate (RR) from the Zephyr™ BioHarness™ over a period of 2 minutes.

In order to obtain a reliable stress assessment during the execution of the training, it is important that the trainees are relaxed during the baseline measurement before the training. It can be problematic if a high stress level is already measured as a baseline and therefore no great increase can be determined during the training scenario. Although the trainee is already

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stressed, a normal stress level is displayed as baseline stress levels are very individual and therefore cannot be compared to “normal” in terms of numbers but can only be compared to the trainees’ individual baseline measurement. If the trainer wants to increase the stress with additional stress cues, this can lead to an overload of trainees. Therefore, it is important for the trainer to know the physical (e.g. cardio health issues) and mental condition (e.g. PTSD) of the trainee before the training starts. But this is the same with non-VR trainings and therefore is part of the trainer tasks when setting up training sessions but should be mentioned here additionally as it might influence the health condition of a trainee.

The algorithm to compute the composite score is as follows:

1. Calculation of HRV with the RMSSD method (Root Mean Sum of Squared Distance) and HR from RtoR Data
2. Calculation of 30 second moving averages after the stressor onset of HRV, HR and RR, as well as fixed averages for the 2-minute windows of the three variables in the baseline condition (Nunan, Sandercock, und Brodie 2010).

   Moving averages: $\mathrm{HRV}_{30\,\mathrm{sec\,mean}}$, $\mathrm{HR}_{30\,\mathrm{sec\,mean}}$ and $\mathrm{RR}_{30\,\mathrm{sec\,mean}}$

   Baseline averages: $\mathrm{HRV}_{2\,\mathrm{min\,mean}}$, $\mathrm{HR}_{2\,\mathrm{min\,mean}}$ and $\mathrm{RR}_{2\,\mathrm{min\,mean}}$

3. Calculation of relative change to baseline for the three variables

$$HRV_{rel} = 1 - HRV_{30\,\mathrm{sec}\,mean}/HRV_{baseline}$$
$$HR_{rel} = 1 - HR_{30\,\mathrm{sec}\,mean}/HR_{baseline}$$
$$RR_{rel} = 1 - RR_{30\,\mathrm{sec}\,mean}/RR_{baseline}$$

4. Calculation of stress level

$$Stress\ score = w_1 * HRV_{rel} + w_2 * HR_{rel} + w_3 * RR_{rel}$$

$$with\ weights\ from\ initial\ model{:}\ w_1 = -0{,}048\ \ w_2 = 6{,}54\ \ w_3 = 0{,}024$$

The computed value for the stress level will be classified in the four categories: 1) normal, 2) increased, 3) high and 4) very high, which are described in Annex.

For the implementation in the SHOTPROS VR training system a buffer of the most recent history of RtoR values is kept. With this data the HR and HRV values and the 30 second means

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are computed. If no values are available due technical issues, this is indicated in the Trainee *Stress Level Assessment* user interface (grey colour and a red cross).

### 7.1.2 Psychological Assessment Method

To assess the subjective levels of stress, anxiety and mental effort of participants in the Human Factor Study in Berlin (HFW2: StressCueValidation, see D6.1) the trainees filled out a questionnaire during the study in which they rated each of the scenarios (see Figure 20, Figure 21, Figure 22) and each stress cue (see Figure 23) on Visual Analogue Scales (VAS). The VAS is broadly used as it is simple and adaptable to a wide range of settings and populations. In the study, the Rating Scale of Mental Effort (RSME; Zijlstra, 1993) and the Anxiety Thermometer (Houtman & Bakker, 1989) to measure state anxiety were applied.

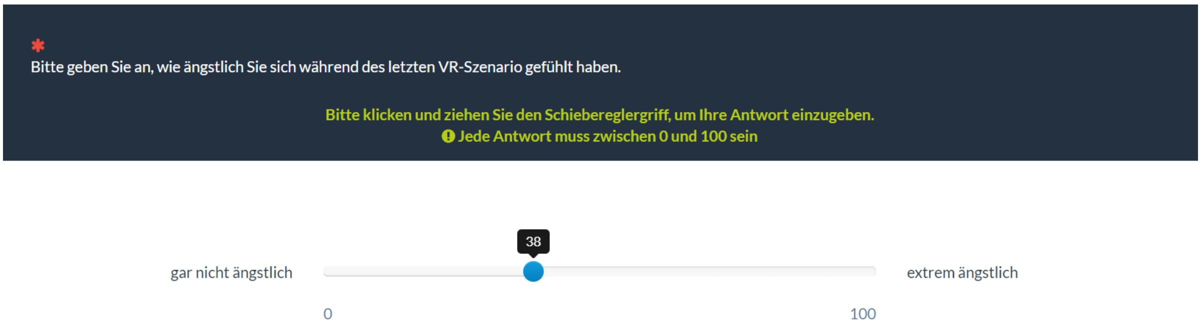


*Figure 20: Questionnaire item for the Anxiety Thermometer: "How anxious did you feel during the last VR scenario?"*

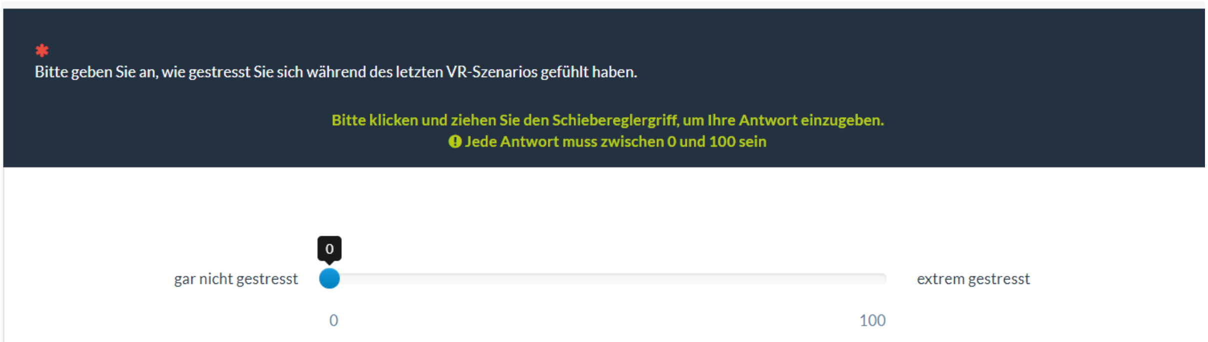


*Figure 21: Questionnaire item for the Anxiety Thermometer: "How stressed did you feel during the last VR scenario?"*

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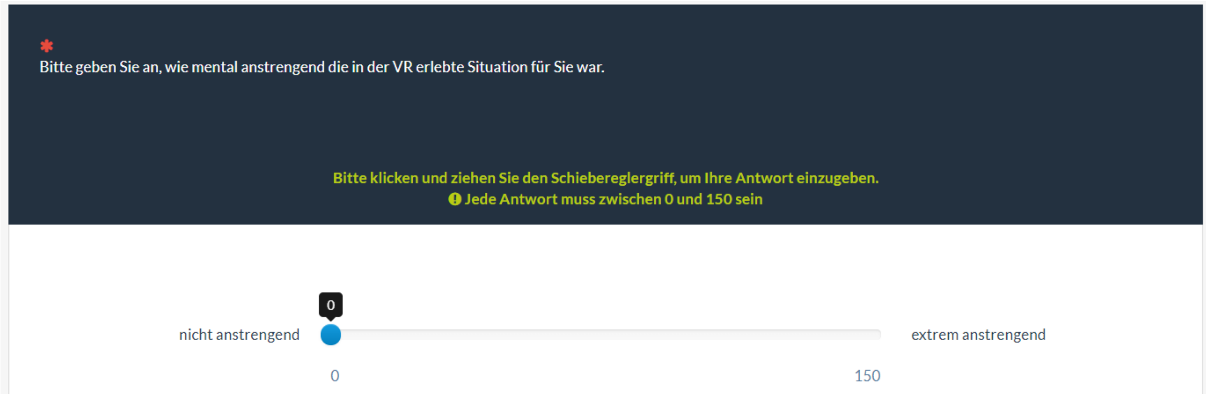


*Figure 22: Question item for Rating Scale of Mental Effort: „How mentally strenuous was the VR scenario for you?"*

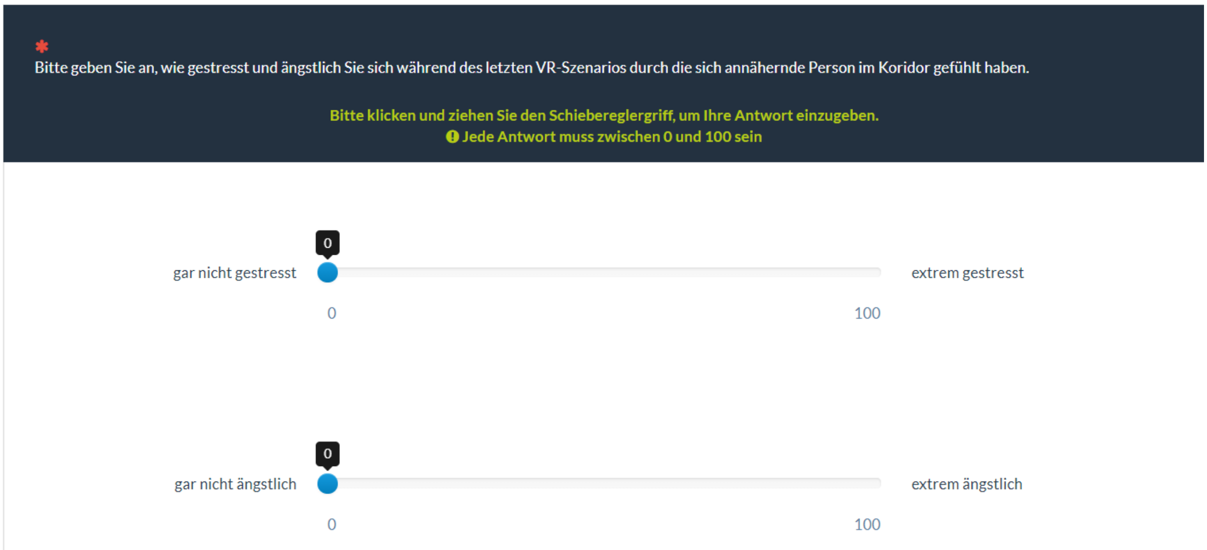


*Figure 23: Question item for Anxiety Thermometer of single stress cues, e.g. "How stressed and anxious did you feel during the last VR scenario because of the approaching person in the corridor?"*

These subjective values were then used in combination with the physiological data collected in the HFW2: Stress Cues study to identify the most effective stress cues. A detailed account of the study and validation of stress cues is presented in the Annex.

## 7.2 Stress Cue Control

The *Stress Cue Control* panel allows to enable and disable stress cues during training in real time. After enabling stress cues, they are directly applied to the actual VR scenario. This panel is based on the newly concept of so-called 'stress cues'. This concept was developed through the SHOTPROS project and will be explained in more detail in the following section.

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### 7.2.1 Concept of Stress Cues

The concept of stress cues operationalises descriptive stressors into concrete, observable and implementable elements in VR to improve the training experience for trainers and trainees. The concept also entails the following components: (a) A stress cue repository, (b) the interaction design for controlling and injecting the selected stress cues in VR via a *Stress Cue Control* panel, (c) a real-time *Stress Level Assessment* dashboard to evaluate and visualise stress cue effects on the trainees.

With the help of the stress cue concept, known real-world stressors for police trainers can thus be implemented to a stress cue repository and used for VR training for DMA-SR. A more detailed account of the stress cue concept and its development can be find found in the scientific SHOTPROS publication (Nguyen u. a. 2021).

Figure 24 shows the implementation of a stressor in VR with audio and/or visual cues in a VR training scenario. The stress cue concept describes the possibility to extend a training scenario with additional stress cues. A scenario consists of a sequence of short situations and moments, so called vignettes, to form an overall storyline. In an ongoing training scenario, a stress cue can be triggered at any time (e.g. the dog starts barking), thus augmenting the original scenario. This allows the trainer to dynamically expand the challenges and the acting of the trainees in a scenario.

The concept of ‚stress cues' was iteratively developed throughout the SHOTPROS project, based on the requirements phase in WP2 (documented in D2.2), based on the findings from workshops as well as further user-centred activities (DEC-TREE, RAT_study1&2, EndUser FeedbackWeek 1, see D6.1 for more details). Based on these activities, we created a list consisting of 40 stressors. The list items were ranked by one LEA trainer expert from each organisation through an online survey. These ranked items were the foundation based on which the stress cues were then iteratively developed.

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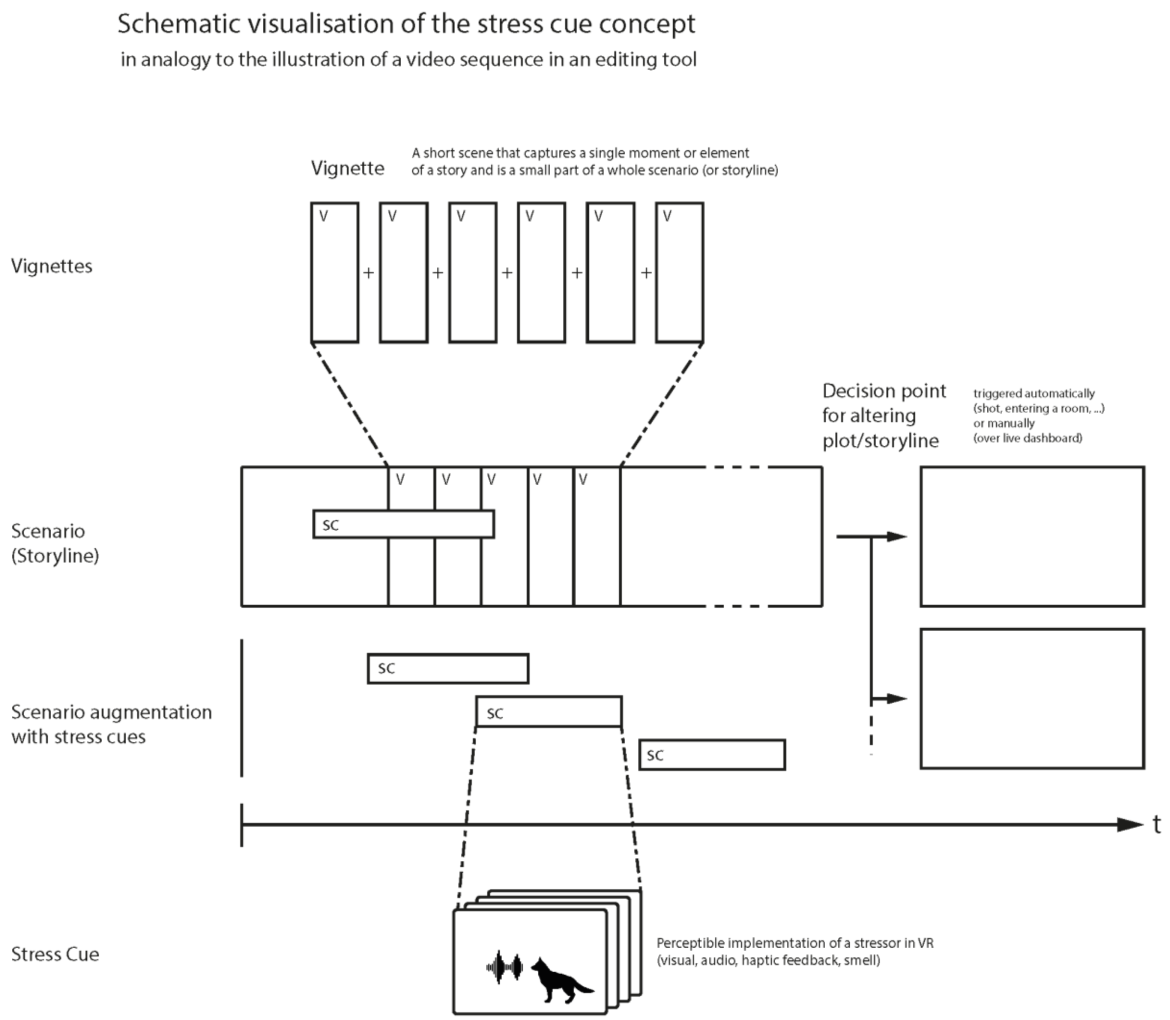


*Figure 24: Schematic visualisation of the stress cue concept with perceptible implementation of a stressor in VR with audio-visual cues.*

## 7.3 In-Action Monitoring

The following section describes how the key performance indicators (KPIs) for training with the VR system were developed for the *In-Action Monitoring*. Based on the SHOTPROS' foundation – an agile user-centred research approach (see D1.1) – the KPIs for training in VR were iteratively developed in a co-creative process with future end users: police trainers. In the context of SHOTPROS, we understand KPIs to mean the computable value of performance metrics that aid in the objective assessment of police officers' and trainees' performance by police trainers.

End users have been and are involved throughout the SHOTPROS project. This includes the requirement workshops *(User_Req,* see D2.2 and D6.1) with 60 participants, the *RAT* studies

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with 550 participants (see D6.1), and the *EndUser FeedbackWeek 2* in Berlin with 47 participants as well as iterative internal discussions with the technology partners and LEAs.

As an additional feedback and information gathering step, an agile co-creation session was conducted in parallel to *HFW3* and the *EndUser FeedbackWeek 3* in Selm, Germany (Figure 25). The focus of this co-creation session lay in both the evaluation and prioritisation of the training KPIs that have been developed so far as well as the conceptualisation of additional KPIs that are relevant for trainers. The findings of the co-creation workshop will also be used for D4.6 and will be validated in the field trials in WP7.


*Figure 25: Impression of co-creation session in parallel to HFW3 and End User Feedback Week 3.*

### 7.3.1 Co-Creation Workshop for KPI Development

The one-day **co-creation** session was conducted with two police trainers who had experience with conducting VR-based police trainings with the SHOTPROS VR system. They can thus be called police training experts for the SHOTPROS project – both as seasoned police trainers and as users of the SHOTPROS VR system. As it had not been possible yet to systematically collect insights from trainers who have been using the SHOTPROS VR system as trainers, this co-creation session was used to focus on specificities and details in the depiction of KPIs. As the

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VR system was in reach during the workshop and the participants had first-hand user experience with it, they were able to hone details of the In-Action Monitoring.

During the workshop, the participants defined specific values required for the KPIs developed so far. For example, a KPI such as “use of baton” needs to be clearly defined in a way that it can actually be implemented into a VR system. For this KPI in particular, they were asked what types of uses exist, and at which point the use of baton should be counted as a statistic (e.g., when pulling out of the tactical belt, when raising as a sign of awareness or when using as a weapon against a perpetrator). These types of questions were asked for all potential KPIs collected so far. In addition, questions such as the value of the KPI (e.g. numerical or other, specific unit of measure, etc.) and whether the trainers wanted a descriptive value or an assessment of the KPI (e.g., good or bad) were discussed. The full list of possible KPIs with inputs from the trainers will be presented in D4.6.

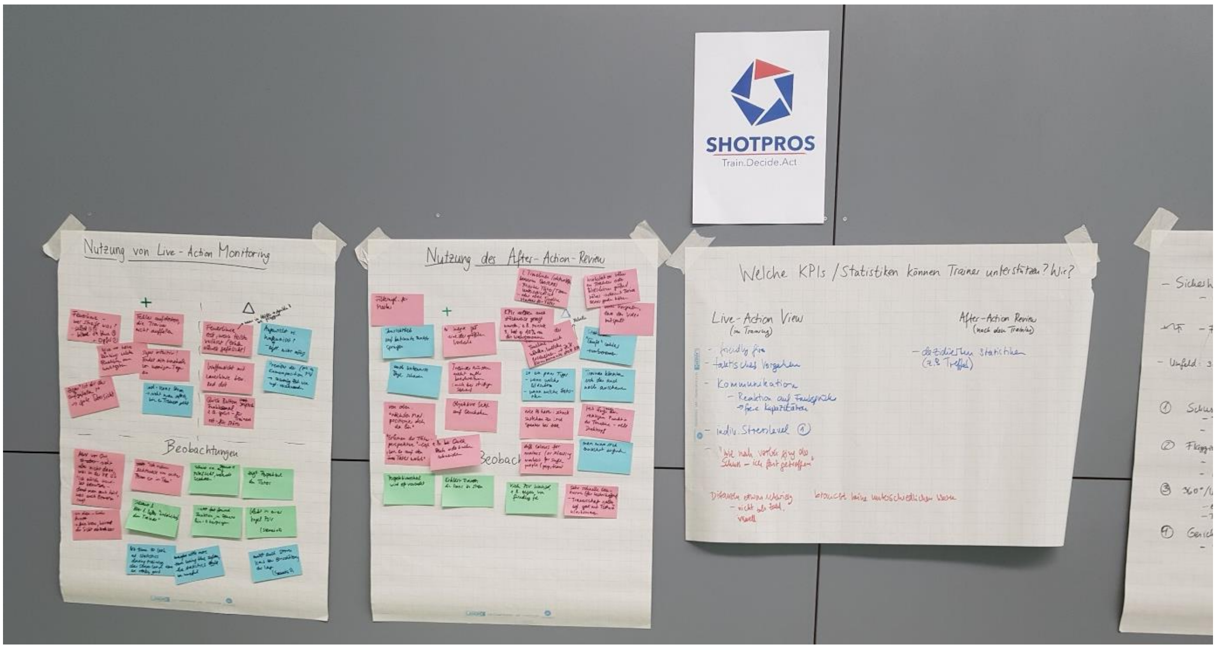


*Figure 26: Collection of feedback and input from trainers in the co-creation session.*

The co-creation workshop also led to a ranked list of the 12 most important KPIs that help trainers objectively assess the performance of trainees as well as how they should be implemented (Table 5). The ranking was developed by the trainers by evaluating which aspects of behaviour in training are most dangerous – for themselves, their own team members, third parties and the attacker/perpetrator. The trainer thus identified four ‘categories’: First, whether shots were fired. Second, whether ‘flagging’ occurred (i.e., whether someone got into the line of fire of a firearm). Third, whether 360° coverage of the

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field of view was achieved. And fourth, whether the trainee was spotted by the perpetrator and to which extent.

For these four categories, the trainers saw a need to be able to view both individual and team KPIs. Furthermore, the KPIs related to firearm use (shots fired and flagging, i.e. having someone in the line of fire) were considered relevant both in terms of how the trainee interacted with their environment as well as how the perpetrator interacted with the trainee. The trainers also added that they did not want the *In-Action Monitoring* through KPIs to be too cluttered. With too many statistics, it would be too confusing and difficult to use. Thus, while all KPIs are helpful and can be extremely relevant for assessing the training, Table 5 displays the KPIs most relevant for basically all types of training interventions. However, even 12 KPIs (for up to 4 trainees) would still be too much input during *In-Action Monitoring*. Considering this, we suggested an interface to allow trainers to select up to 5 KPIs that the trainer in question deems to be most relevant for training assessment for each training scenario in advance (see chapter 6, Figure 15).

While the described methodology provided immensely helpful insights into the knowledge and needs of trainers with experience with the SHOTPROS VR system, the presented *In-Action Monitoring* and developed AAR features (described in future deliverable D5.4) will also be validated with experienced police trainers during the planned field trials (in WP7). The final selection of the KPIs will then be implemented as part of the final development release. The concrete recommendations will be reported in WP7.

### 7.3.2 The 12 most important KPIs for In-Action Monitoring

The following Table 5 provides a list of the 12 most important KPIs that help trainers objectively assess the performance of trainees as well as how they should be implemented (calculation and measurement of the KPI).

These developed and validated KPIs will be implemented in the SHOTPROS VR system and evaluated in the planned field trials (WP7).

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**Top 12 Training 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)?<br>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 | TEAM | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | discharged by all team members | | |
| **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 | |
| **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 | TEAM | Group size usually of 2 or 4; preferably, trainers |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | covering via their FOV? | | 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 5: List of 12 highest-rated KPIs for In-Action Monitoring by police trainers.*

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# 8 Results and Impact for LEAs

This deliverable D4.5 describes how the **Real-Time VR Trainer Dashboard** works and how the creation process for the features is approached. The **four central functions** with *Live VR View*, *Stress Level Assessment*, *Stress Cue Control* and *In-Action Monitoring* are explained and the mode of operation for the trainer is described. An additional focus was the **calculation of the live stress score and the classification into four levels** (normal, increased, high and very high) and its **visualisation** for the VR trainer.

As mentioned, the four functions have already been transferred by the agile core team into the product backlog (see D1.1) and taken into account in the current release planning. Core functions from the tool were evaluated in several agile feedback loops (see D6.1 with the focus to the EndUser FeedbackWeeks and the HFWeeks1-3) with LEAs and new insights were directly incorporated into the agile development process (see D1.1).

Further, the stress cues were evaluated, and it was found that they indeed lead to physiological changes in the suspected directions, which supports the use of both the stressors as well as the physiological measurement method for the likelihood of stress. Another finding strengthening the usage of the three proposed variables (HRV, HR, and RR) was the fact, that we could differentiate between highly experienced and less experienced participants – with the experienced officers appear to experience lower levels of stress, as they have a lot of routine.

**Training objectives**

Objectives of a training need to be defined clearly in advance of the training (also see D3.3) and they should be achievable and measurable – if somebody executes the training he achieves these learning goals. They build the beginning of a training to learn knowledge, skills and attitudes, e.g. scanning a room, personal safety – distance to the suspect, use of force, conflict management/de-escalation, traffic control procedures, etc.

After defining the training objectives, it is important to select the appropriate stress cues. As in D3.3, it is important to find the proportionality and to create a suitable stress level and not to choose an exaggerated one.

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# 9 Conclusions and Next Steps

The presented core functionalities and the future possibilities of the "'After-Action Review" (reported in D5.4, M33) are highly relevant for an innovative VR training system in the police field and represent a clear unique selling proposition (USP) compared to existing VR solutions on the market and will be elaborated and explained in more detail in the D8.6 "Exploitation Plan, Innovation Management and Business Outlook" (M42).

Especially the possibilities for the police trainer to directly intervene in the VR session, the live visualisation of the trainees in relation to the SHOTPROS stress topic as well as the immediate information on different key performance indicators are a clear differentiation from current products and offer enormous future potential. Thus, the results from this deliverable expand the other SHOTPROS core major innovations (e.g. size of the VR training surface up to 70x100m, tangible tactical belt, fast adaptation of scenarios and the training curriculum) with new results and methods (e.g. the machine learning approach in estimating the likelihood of stress) and add up to a high innovation potential for future market strategies.

In the next step, the D5.4 "VR Results Dashboard for Reviewing and Measuring Training Sessions Performance and Output for Evaluation and Field Trials" is finalised with the focus on the After-Action Review (AAR), the two deliverables (D4.5 and D5.4) have a strong correlation (D4.5 focusing on "during training session" and D5.4 focusing on "after training session"). Thus, D4.5 provides essential inputs on the stress level and the defined performance KPIs from the real-time perspective, which are then analysed in D5.4 from the cumulative perspective of the entire VR training session.

For the planned field trials in Q1 and Q2 2022 (see WP7), the presented features will be finally implemented, validated and evaluated with different end users. These validated results will then be incorporated into the final SHOTPROS demonstration tool (D8.7, M34).

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# 11 ANNEX I: Validation of Stress Cues

To design training scenarios for DMA in stressful and high-risk situations in VR, suitable stress cues must be incorporated. For this purpose, it is necessary to know which cues induce stress and how strong the effect is in VR. To assess stress inducing capabilities of the initial stressors (described in D4.1) an empirical HF study was conducted in Berlin and is described in the following. The study was planned to be conducted earlier in the SHOTPROS project (summer 2020), but due to the COVID-19 pandemic, it could not be conducted as planned and the stress cue repository in D4.1 does not include the results of the final validation. For this reason, the description of the stress cue study to validate the stress cue repository and its results are listed here.

## 11.1Stress Cue Study (Berlin)

The study took place at the premises of the SHOTPROS partner Berlin Polizei (BP) with police officers as test participants. Stress was assessed through subjective reports (Task Load Index, Analog-Visual scales) and physiological measures (HRV, HR, RR and saliva samples for alpha-amylase and cortisol).

### 11.1.1 Aims and Objectives

The aim of this study was to empirically proof the ability of the stressors as described in D4.1 to induce stress responses and create respective immersion for trainees in VR environments in order to identify well performing stressors for utilisation in follow-up studies and for the VR training.

This study will contribute towards objectives 2, 3 and 4. Furthermore, it will feed mainly into the work packages 4 and 5 and through the scenarios defined for the field trial in T5.3 it will feed into WP7.

### 11.1.2 Study Execution

25 participants from BP went through four assessment sessions using a VR research prototype (see D4.1) including different stress cues, including one baseline measurement.

To ensure cortisol and alpha amylase levels were not influenced by external factors, participants were asked not to consume food, caffeine or nicotine at least 2 hours before the start of the study. To trigger a potential cortisol response in the scenarios, a person needs to be exposed to stress for at least 3 minutes, therefore each session includes a combination of scenarios with several different stress cues:

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| | *Stress Cue* | *Description* |
|---|---|---|
| 01 | Barking dog | Dog barks in the corner and walks towards trainee |
| 02 | Stranger pulling a weapon | A strange man is walking towards the trainee and pulls his gun |
| 03 | Injured person | Injured, non-responsive person is laying on the floor |
| 04 | Blood | Traces of blood can be seen in the room. |
| 05 | Stranger with weapon | A strange man holding a gun is walking towards the trainee |
| 06 | Being filmed (day) | The trainee is followed by a man pointing a phone camera towards them, during the day |
| 07 | Scream | Screams are audible while trainee is inside a closed room/or outside (e.g. on the street) |
| 08 | Being filmed (night) | The trainee is followed by a man pointing a phone camera towards them, during the night |
| 09 | Falling rocks | Rocks are falling on the trainee from above |
| 10 | Loud unexplained noise | Door is banged shut after trainee walked inside the room / In closed room, the TV is running and producing loud sudden sounds. |
| 11 | Child & hysterically laughing person | A child is cowering in the corner while a grown-up man is sitting on the couch laughing hysterically |
| 12 | Loud noise | A loud scream can be heard from an adjacent room |
| 13 | Unknown origin of smoke | Room gets filled with smoke |
| 14 | Dark room | Lights suddenly shut off while trainee is in the room |
| 15 | Stranger | Unidentified man walks into the room |

*Table 6: Stress Cue Overview.*

Each day, five participants went through the following study sessions:

**Session 1: Baseline Measurement**

Trainees were required to stand in front of a white wall, look straight ahead, relax and breath calmly for two minutes. The Zephyr™ BioHarness™, trainees were wearing, recorded the baseline bio signals.

Afterwards trainees put on the VR headset HTC Vive Pro Eye, calibrated the headset to their individual eyes and went through a baseline scenario for approximately three minutes, in order to get accustomed to the VR technology, learn how to open doors with the VR controller and record another baseline within the virtual environment. The baseline scenario did not include any stress cues.

**Session 2: Scenario 1A (Dog) & 1B (Crime Scene)**

In the beginning of the first scenario 1A, participants listened to a message from the police operator via the "pretend" police radio:

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*"A resident of an apartment building called because he heard strange noises from the neighbour's apartment, who is known to be away on holidays. The trainee is asked to investigate the situation."*

The trainee enters the VR in the hallway of the apartment building and starts to walk through the hallway to enter the apartment. During his investigation in the apartment, he encounters the following audio-visual stressors: In the living room a barking dog approaching, then a whistle sounds, and the dog runs beside the trainee out of the room. Following the dog an aggressive stranger is approaching on the gangway and draws a gun.

The second scenario 1B in this session starts again with a message on the police radio, informing the trainee about reports of a gunshot in an apartment building.

The trainee enters the VR in an anteroom of an apartment and starts to walk towards the door to the living room. When he opens the door, it is quite dark with a flickering light in the room, which turns off as soon as he enters the room. The light switch does not work. While scanning the room traces of blood can be seen which lead to an injured, non-responsive body lying on the floor. A loud scream is heard from an adjacent room, when trainees walk towards the door to follow the sound they encounter a stranger with a weapon. This appeared only to four of the test persons since the trigger was not released.

Stress cues included:

(a) Barking dog
(b) Stranger holding a knife
(c) Injured/dead body
(d) Stranger holding a gun


*Figure 27: Scenario 1A including a dog and stranger holding a weapon.*

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**Session 3: Scenario 2A / 2B / 2C / 2D (Outdoor Scenes)**

Trainees receive information via the police radio about a growing crowd in a public outdoor space including people under the influence of alcohol, displaying aggression. Several reports of molestations and violence were received. A second unit is on its way. Trainees are asked to investigate the situation and report back.

Trainees enter the VR and find themselves in an empty street, in front of a large building. The only person in the street is a man pointing a camera at the trainee. If trainees try to engage with the stranger, he does not respond.

In the next scenario (2B) they are in the same empty street but at night. Suddenly a distant scream can be heard.

The next scenario (2C) includes a man filming the trainee in a night scene.

In scenario 2D, rocks are falling from above while trainees walk through the outdoor space.

Stress cues included:

(a) Confusing situation (radio message does not match scenario)
(b) Photographer during day
(c) Night scene including loud scream
(d) Photographer during night
(e) Stones falling from above

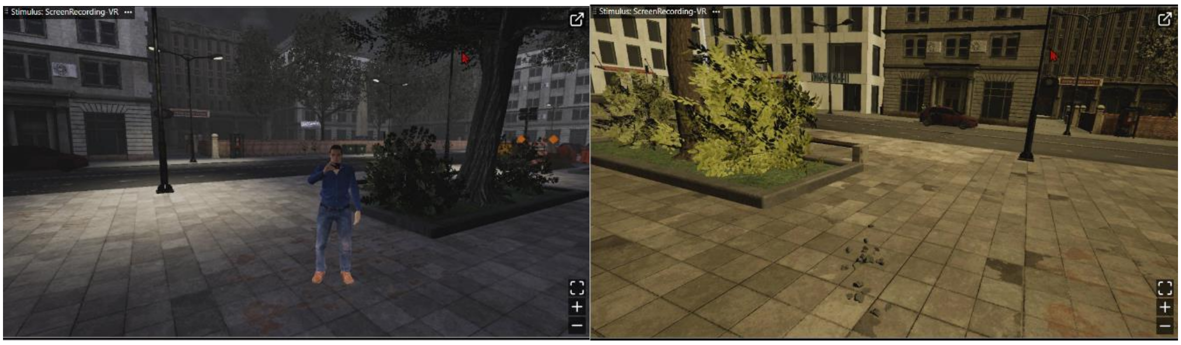

*Figure 28: Outdoor scenario 2C and 2D.*

**Session 4: Scenario 3A / 3B / 3C / 3D / 3E (indoor scenes)**

In session 4, trainees went through five individual scenarios each including some stress cues.

In scenario 3A, a loud noise can be heard as the door of the room the trainee is in suddenly shuts.

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In scenario 3B, the trainee finds a crying child, cowered in the corner of a room, while a man is sitting on the sofa laughing hysterically.

In scenario 3C, trainees walk into an empty room as a scream from another room or the hallway can be heard.

In scenario 3D, smoke develops as the trainee walks into a room.

In scenario 3E, the light suddenly turns off as trainees walk around the room.

In scenario 3F, an unannounced stranger walks into the room of the trainee.

Stress cues included:

(a) Sudden noise by closing door
(b) Crying child
(c) Person hysterically laughing
(d) Scream
(e) Smoke
(f) Dark room
(g) Stranger

*Figure 29: Screenshots from the VR Scenario 3B and 3E*

Saliva sampling took place at the following points in time:

1. Baseline: before the VR sessions begins
2. Directly after session 1 (baseline & baselines scenario) finished
3. Directly after session 2 (scenario 1a & 1b) finished
4. 20 minutes after first stressor onset in scenario 2
5. Directly after session 3 (scenario 2a /2b /2c /2d) finished
6. 20 minutes after first stressor onset in session 3

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For the last session (4) no saliva sample was taken so participants were able to eat and drink during the lunch break.

The following equipment was used for this study:

- Scenario development software: Unreal Engine v4
- User experience platform: SteamVR
- VR headset and controllers: HTC Vive Pro Eye
- Laptop: Dell Alienware R3
- Bio signal measurement: Zephyr™ BioHarness™
- Data recording software: iMotions (Figre 30)

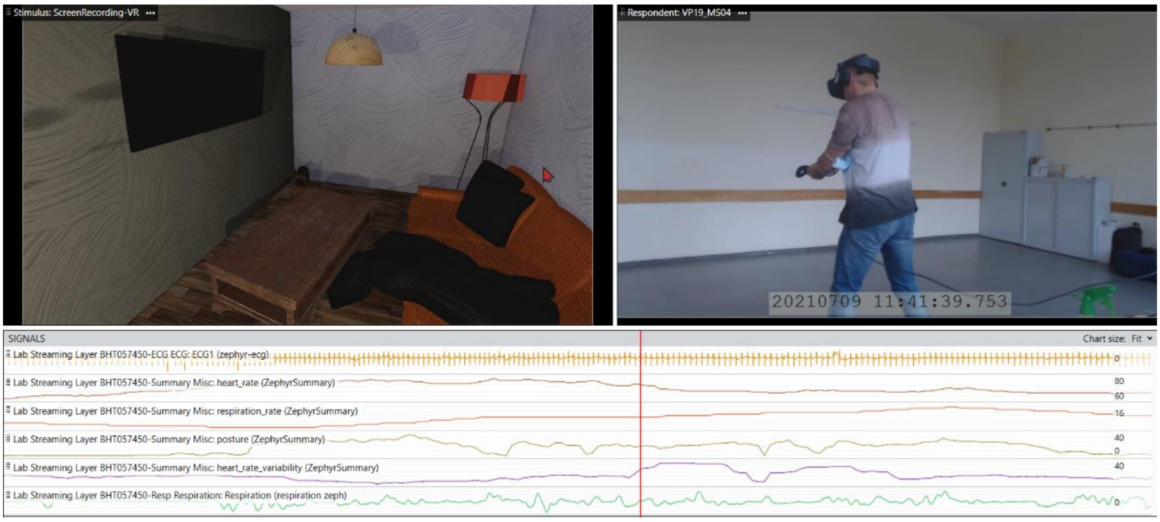


*Figure 30: Screenshot of iMotion view during the study.*

### 11.1.3 Analysis and Results of Berlin Stress Cue Study

For a descriptive analysis of the collected data from the HFWeek2 Study (see D6.1), the synchronised and timestamped data from the Zephyr™ BioModule™ was scanned for the occurrence of the 15 stressors. Following the onset of a stressor, a 30-second window was mapped, to aid the further analysis. Additionally, to the stressors, the baseline-condition was mapped. The 30-second slices of data resulting from this were averaged across participants. The baseline-average was subtracted from the stressor averages to obtain the difference to the baseline measurement, an indicator of the impact of the stressors. This was done for three suspected main variables: heart rate (HR), heart rate variability (HRV) as well as the respiration rate (RR). Figure 31, 32 and 33 show the averaged differences to the baseline following the onset of the stressors for all participants, split by work experience. The sample consisted of N

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= 14 trainees with little real-life experience on the job and of N = 8 experienced participants with 20+ years of experience.

The HRV showed mixed results in the two groups: whereas the HRV did not change much for the experienced participants, it generally dropped for the less experienced trainees (see Figure 31). We take this as an indicator, that the less experienced participants exhibited a higher amount of stress, whereas the experienced participants know the real-life equivalents of the stressors and therefore experience less stress. As expected, the heart rate generally went up in both groups following the onset of a stressor. Interestingly, the experienced participants exhibited a higher increase in heart-rate after the onset of the stressors when compared to the less experienced participants – but in both cases the reaction to the stressors generally was an increase in heart rate (see Figure 32). The RR generally increased following the onset of a stressor for both groups (see Figure 33).

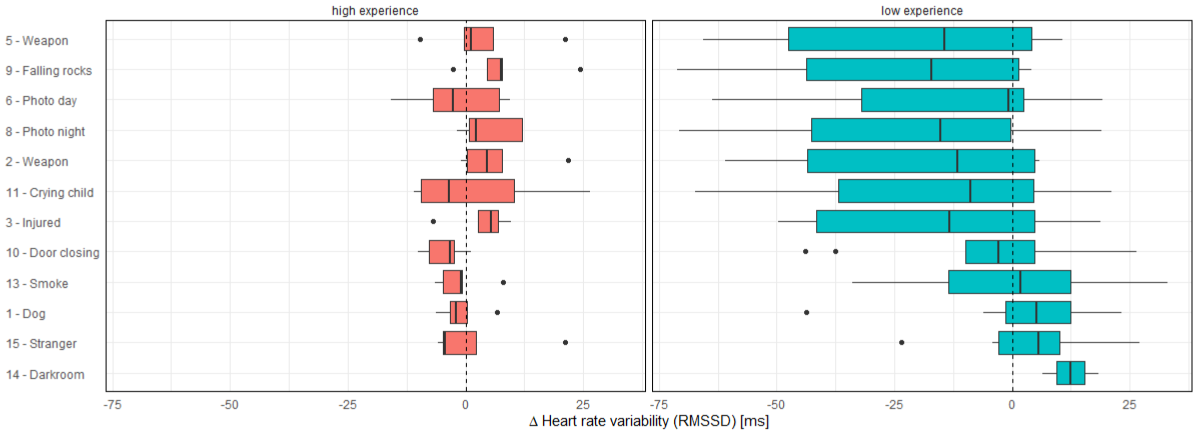


*Figure 31: Mean Differences of heart rate variability (RMSSD) to the baseline condition of the stressors, split by work experience.*

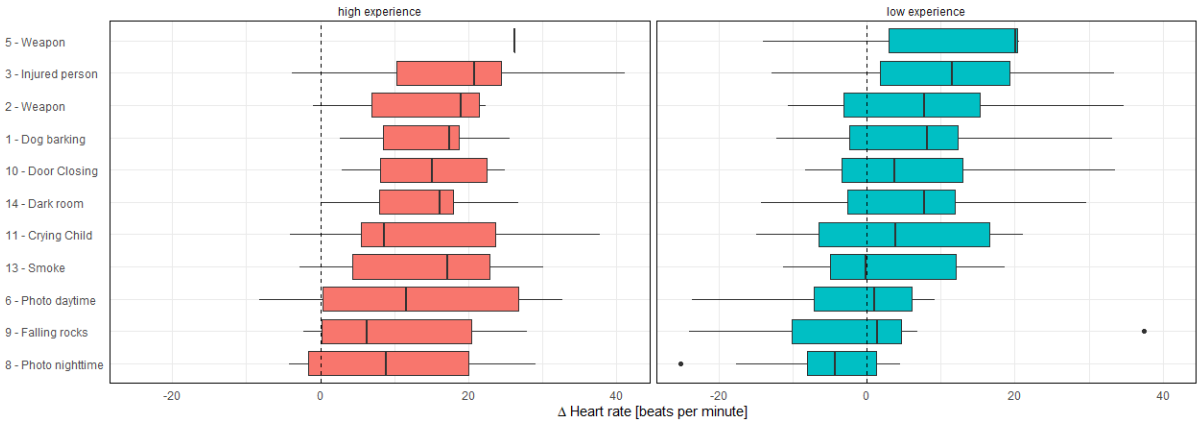


*Figure 32: Mean differences of heart rate to the baseline condition of the stressors, split by work experience.*

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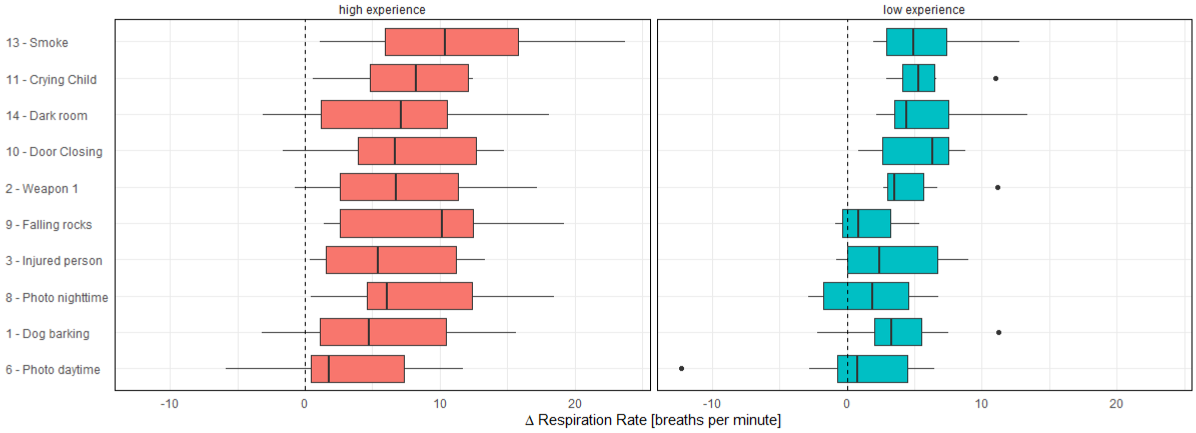


*Figure 33: Mean differences of respiration rate to the baseline condition of the stressors, split by work experience.*

These means of differences resulted in a ranking of the stressors, which was completed by subjective stress ratings of every stressor. The four rankings can be found in Table 7. A Spearman-Rank correlation was done on the combined rank of HR, HRV and RR and the subjective ratings of the stressors, which resulted in a very high, statistically significant accordance of the two rankings ($r_s$ = 0,9), meaning that the three physiological variables together resulted in a very similar ranking as the self-ratings.

| | $r_s$ | t-value | p-value |
|---|---|---|---|
| **HRV Rank ~ Self Rating Rank** | 0,35 | 1,11 | 0,296 |
| **HR Rank ~ Self Rating Rank** | 0,57 | 2,10 | 0,066 |
| **RR Rank ~ Self Rating Rank** | 0,38 | 1,23 | 0,251 |
| **Combined Rank ~ Self Rating Rank** | 0,90 | 6,02 | < 0,001 *** |

*Table 7: Spearman Rank Correlations of heart rate variability, heart rate and respiration rate, as well as the combined rank of the three variables (mean of the three ranks).*

As the combined rank from all three bio signals resulted in a very good match to the subjective ratings, we decided using all three (HR, HRV and Respiration rate) for a combined measure of the likelihood of acute stress in real-time. As a working-model (validated during the field trials planned in WP7) we recommend a composite score of relative change to the individual baseline of the three variables (HR, HRV and Respiration rate).

To refine this model of stress, the large amounts of data that will be collected in future studies and field trials of the project will serve as a basis for a more elaborate model. The percentile change to the individual baseline will be weighted within a multiple regression model. These weights will be adjusted using a machine learning algorithm, which will take in the means of the 30 seconds following the stressor onsets of the three variables, calculate the percentage difference to the individual baseline and use the resulting variables as predictors in a multiple

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linear regression, with the subjective rating of the trainee as a dependent variable. As more and more data come in, the resulting model will increase in accuracy, with better weights and an increased quality of the likelihood of stress measure.

To initialise our model, we calculated the multiple regression with data of the top 5 stressors, to get the initial weights. As the dependent variable ranges from 0 to 100, a fixed intercept of 0 was chosen, meaning that no change in the three variables should lead to a stress score of 0. The regression resulted in the following calculation for stress:

$$Stress\ score = (-4{,}8 * \ HRV_{rel} + 65{,}4 * \ HR_{rel} + 2{,}4 * \ RESP_{rel})/100$$

The resulting weights are as follows:

$$w_1 = -0{,}048$$
$$w_2 = 6{,}54$$
$$w_3 = 0{,}024$$

As the training of the multiple regression model was done on the subjective ratings (visual analogue scale) with a range from 0 to 100, the prediction of the regression has to be divided by 100 to obtain a stress score between 0 and 1. The intercept of the regression is fixed at 0, so that no change in the three variables results in a stress score of 0. Based on the common interpretation of the VAS (Jensen, Chen, und Brugger 2003), the ranges of our stress score depicted in Table 8 will correspond to the four stress levels mentioned earlier. As $HRV_{rel}$ can get positive, and $HR_{rel}$ and $RR_{rel}$ can get negative (i.e. indicating lower stress in the training scenario that in the baseline scenario), negative values for the stress score are possible. As this indicates an absence of stress, all negative values will be classified as "normal" for the stress level.

| From | | To | Stress level |
|---|---|---|---|
| **negative** | - | 0,04 | Normal |
| **0,05** | - | 0,44 | Increased |
| **0,45** | - | 0,74 | High |
| **0,75** | - | 1,00 | Very High |

*Table 8: Ranges for the stress score*

The evaluation of the stress scores for the individual stress cues led to the following ranking of the cues according to the mean rank (Table 8). Comparing the results with the LEAs' rankings shows that they are not exactly the same, but the highest and lowest scores match well.

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| Stressor | HRV | HR | RR | Mean Rank | Self-Rating |
|---|---|---|---|---|---|
| **05 Stranger with weapon** | 1 | 1 | na | 1 | 2 |
| **02 Stranger pulling a weapon** | 5 | 3 | 5 | 2 | 1 |
| **11 Child & hysterically laughing person** | 6 | 7 | 2 | 3 | 5 |
| **03 Injured person** | 7 | 2 | 7 | 4 | 4 |
| **10 Loud unexplained noise** | 8 | 5 | 4 | 5 | 6 |
| **13 Unknown origin of smoke** | 9 | 8 | 1 | 6,5 | 7 |
| **09 Falling rocks** | 2 | 10 | 6 | 6,5 | 3 |
| **14 Dark room** | 12 | 6 | 3 | 8 | 8 |
| **06 Being filmed (day)** | 3 | 9 | 10 | 9 | 10 |
| **01 Barking dog** | 10 | 4 | 9 | 10,5 | 9 |
| **08 Being filmed (night)** | 4 | 11 | 8 | 10,5 | 11 |

*Table 9: Rankings of the stressors based on the three variables (heart rate variability, heart rate, respiration rate). Four stressors (scream indoor, scream outdoor, scream, stranger) were excluded in the data cleaning process.*

### Implementation within the VR system

Based on these findings (especially the final rankings of the stressors) the relevant stressors will be selected and used within the upcoming VR scenario for the planned field trials (see WP7). Therefore, the selected stressors will be developed during the agile process regarding the concept of stress cues.

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