EPICSAVE - Enhancing Vocational Training for Paramedics with Multi-user Virtual Reality

Jonas Schild
Hochschule Hannover
University of Applied
Sciences and Arts
Hannover, Germany

Dieter Lerner
Fraunhofer Institute for
Experimental Software
Engineering IESE
Kaiserslautern, Germany

Sebastian Misztal
Hochschule Hannover
University of Applied
Sciences and Arts
Hannover, Germany

Thomas Luiz
Fraunhofer Institute for
Experimental Software
Engineering IESE
Kaiserslautern, Germany

***Abstract*— An anaphylactic shock constitutes a representative scenario for critical paramedical cases that happen too rare to eventually occur within a regular curricular term of vocational training. As a possible solution, this paper presents EPICSAVE, a development case that yields novel training tools using multi-user virtual reality (VR) and serious game methodology. The case describes the interdisciplinary setup and iterative workflow of the development of a simulation prototype. Examples show design tools and methodologies, e.g., finding focus in medical treatment. Results from two pilot studies indicate that specifically multi-user VR may enhance paramedic training. The subsequently developed prototype offers collaborative training for two paramedic trainees and one trainer. Results from a user study with paramedic trainees indicate that experiencing a positive VR training outcome depends on high presence effects and is limited by usability issues. We provide a list of open design and usability issues that shall help to improve future integration of multi-user VR in training facilities.**

Keywords*— *medical vocational training; virtual reality; educational virtual environments; multi-user VR:, simulation; serious game;

I. Introduction

A. May VR Serious Games enhance paramedic training?

Rare exposure to critical emergencies, such as the severe anaphylactic shock, makes practical training within the limited time frame of a vocational curriculum challenging [1]. Such emergencies typically involve varying team constellations and environments, limited patient information, low tolerance to errors, and time pressure. Besides structured procedures based on medical algorithms, experience helps paramedics to develop competence in coordination of task- and teamwork in dynamically changing situations. Such comprehensive competence can hardly be acquired through existing training methods, i.e. involving high-fidelity simulators based on simulation phantoms or even professional actors. Additionally, such methods require high effort of personnel, material and time, with limitations in offering a simulation of dynamically fluctuating symptoms and vital signs, involving several organ systems (e.g. skins, airways, cardiovascular system) [2, 3]. As solution to this lack of training of collaborative tasks in dynamic settings, we propose developing novel training tools based on multi-user VR and serious game technology (see Fig. 1), as also regarded promising by other researchers [4].

Fig. 1. The EPICSAVE simulation prototype in use with two paramedic trainees in multi-user VR and two trainers.

B. Challenges and opportunities

Key challenges are the technical and content-wise development of such new training tools and their integration into vocational training centers. While recent evolution of consumer VR technology and game development tools can drastically increase resulting quality of interactive simulations, the possible scaling of investment is incredibly large, looking at successful commercial game productions now reaching more than 50 Mio $ budgets, with some games costing several hundreds of Millions. What kind of investment is necessary to create a significantly advantageous effect, which overall extends existing training methods and hence improves quality of training?

C. Finding focus in interdisciplinary, iterative development

Simulation fidelity and graphical quality directly scale with investment, requiring personal-intensive 3D modeling, animation, texturing, and material shader editing. Hence, we must generally reduce complexity; we must find focus in medical and technical content, to provide interactivity, decision-making, and collaboration on a relying level. Such a relying level is a compromise of realism vs. abstraction, aiming at supporting users in transferring competence towards real situations. Finding such compromises is one of many tasks in a development process that leads to a successful VR serious game. According to Dörner et al. [5], the general methodology for

978-1-5386-6298-4/18/$31.00 ©2018 IEEE

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.

creating such novel media typically involves experts from multiple areas developing iterative steps through agile software engineering. The actual process depends on the actual problem space and needs adaptation, called "design your design" [6]. The goal of this paper is to pave the way for other developers by presenting, describing and assessing a concrete development case: A interdisciplinary project consortium develops a practicing system for paramedical vocational training that aims at combining serious game technology with virtual reality in concert with curricular modeling and implementation at paramedic services. The development process takes three years with two iterations, one simulation prototype and one subsequent serious game prototype to follow. This paper describes the development case of the simulation prototype, i.e., the setup, requirements analysis, development, and evaluation, between March 2016 and November 2017.

II. Related Work

Virtual Reality (VR) technologies and Serious Games (SG) have become powerful and promising tools in education because of their unique technological characteristics. A large number of studies shows that both technologies support effective teaching and learning.

A. *Virtual Reality-Simulation*

Immersive virtual environments (VE) have been adopted as cost-effective solutions for creating simulations in a vast set of areas, including healthcare and emergency medicine. Multi-user VEs enable social interaction through several multisensory channels; they also support coordination actions, allow cooperation settings, and improve collaborative learning [7, 8]. A meta-analysis by Consorti et al. of 12 studies showed a clear positive overall effect of using virtual patients as educational interventions, compared to other educational methods [9]. The authors define a virtual patient as an interactive computer simulation of real-life clinical scenarios for healthcare and medical training, education or assessment. Merchant et al. [10] examined in their meta-analysis the impact of selected instructional design principles in the context of desktop-based VR-based instruction for the categories of games (13 studies), simulations (29 studies) and virtual worlds (25 studies). The meta-analysis revealed statistically significant positive effects of all three categories on learning. A moderator analysis further showed higher learning gains for games than for simulations and virtual worlds.

Flores et al. [11] describe a clinical case simulator called SimDeCS using a 2D non-multi-user environment with focus on model-learning supported by artificial intelligence. A student can enter a dialog with a virtual patient. Interactions between agents use textual dialogs. Results from applying a self-designed questionnaire indicate that participants find SimDeCS motivational; they believe that it can be an effective remedy education tool and the students retain knowledge after using it. Zielke et al. [12] evaluated advantages and disadvantages of VR and augmented reality in patient applications. The authors describe drawbacks of their learning platform "UT TIME Portal", e.g., text- and monitor-based interface, less immersive and less natural experiences. They see a considerable potential in using a 3D environment with head-mounted displays. Students further suggested to implement non-verbal techniques like body language and eye contact to switch attention between patient and caregiver.

B. *Serious Games*

Recent literature reviews and meta-analysis confirm the impact of games on learning [13]: A meta-analysis, carried out by Wouters et al. analyzed 39 studies focusing on comparisons of knowledge, skills, retention, and motivation outcomes in serious games. Wouters et al. found that SG were more effective than conventional instruction in terms of learning and retention, but they found no evidence that SG were more motivating [14]. In their systematic review of serious games in training health care professionals Wang et al. synthesized current serious gaming trends in health care training. 19 studies (for 33 games) reported learning effects, whereas only two studies found no significant differences between study group and control group [15]. With the VR-based SG DocTraining [19] medical students can train to diagnose symptoms of virtual patients while professors can observe and assess knowledge. The application creates symptoms, diseases and samples in a machine-learning algorithm using real data but symptoms are mostly limited to textual depictions. In comparison to our approach, interaction between players is restricted to verbal communication. DocTraining uses GoogleCardboard-based VR, which limits interaction fidelity by the lack of supporting 6-DOF input devices. DocTraining has not been evaluated yet.

III. Development setup

The main goal is to showcase whether and how VR technology can enhance medical training, that includes analysis of development methods, focus in medical content, creating appropriate technology solutions and evaluation methodology, as well as identification of existing hurdles that we need to resolve to lead to future market and product development.

A. *Interdisciplinary setup*

The publicly funded project EPICSAVE (www.epicsave.de) involves an interdisciplinary cross-regional consortium that incorporates expertise from all relevant disciplines, i.e., paramedic training academies, media education, VR and gaming technology and arts, serious game design, commercial serious game and simulation production and sales. Hence, collaboration requires management of interdisciplinary design and implementation tools that offer remote functionality. The remainder of this section discusses the actual workflow, presents chosen design tools and co-working arrangements.

B. *Overview of the iterative, interdisciplinary work-flow*

The overall workflow (see Fig. 3) is an iterative process over the course of a three-year project, constrained by external funding with an overall budget of nearly 2 Mio €. The process consists of a requirements analysis, followed by two iterations of a set of design, implementation and evaluation phases that lead to two subsequently developed prototypes.

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.

Fig. 2. Impressions from four training sessions on two paramedic training sites. Upper row at Akademie für Notfallmedizin der Hansestadt Hamburg (left to right): adult phantom simulator outside a train wagon, same scene from a view of a 360° camera. child phantom inside train wagon setup and actual training session. Lower row at Malteser Bildungszentrum HRS in Wetzlar (from left to right): outdoor park scene with adult phantom, transport in ambulance car, indoor scene with actor, transport through stair case. All scenes were filmed using two 360° cameras and additional mobile phones.

C. *Requirements analysis and pilot study*

After starting the project in March 2016, the phase of requirements analysis of vocational training practice began. This phase involved the analysis of the target groups (trainers and trainees) and the analysis of the medical content.

1) *Analysis of target groups*

We created a target group survey for trainees of the two paramedic academies (n=31, across the two educational institutions). This study provided important insights for the development of learning and competence goals and for the user experience concept. As one part of the target group analysis, a learning style diagnostic with the Kolb Learning Style Inventory was carried out [17]. In our sample, a learning style based on active and experience-based learning style predominates (74 %). The results suggest that trainees prefer methods and technologies in which they can actively translate their knowledge into actions.

2) *Analysis of Gamification User Types*

We conducted an analysis of gaming preferences using the 24-items Gamification User Types Hexad Scale [18]. The scale includes six user types: Philantropist, Socialiser, Free Spirit, Achiever, Player, and Disruptor. The reportedly predominant type of user are Philanthropist and Socializer, but also Achiever. Disruptive play is not preferred. In each case, two substantial parts of the participants (each about 42%) stated that they either (1) played regularly (several times a week or more often) or (2) only occasionally during the year or not at all. The preferred platform was surprisingly local multiplayer, which is currently less common than the local single-player mode, mobile games or networked online games, but the preference seems to reflect the team spirit of pre-clinical emergency medicine.

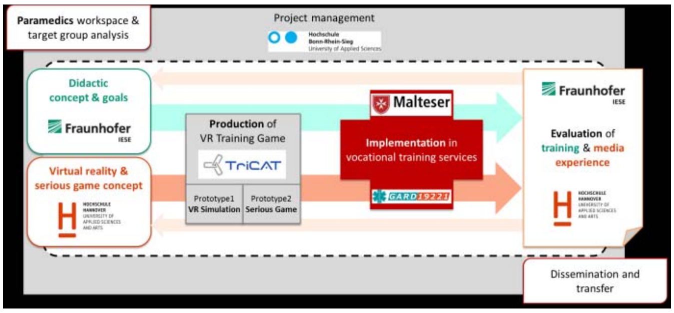

Fig. 3. The iterative work-flow showing two prototype iterations to be developed by an inter-disciplinary consortium.

3) *Analysis of emergency medical procedures*

This analysis aimed at introducing both educational and technology researchers to processes and conditions of emergencies. The consortium arranged two on-site assessments at different paramedic training academies. Both events consisted of two training sessions with instructors, trained emergency paramedics, actors or simulator phantoms and medical staff (see Fig. 2). These runs were filmed with two 360-degree cameras to capture the process as well as the training environment. We then examined the evidence-based guidelines for treatment of anaphylaxis and studies that highlight common mistakes in pre-hospital treatment and care of patients with anaphylaxis [19].

Based on these analyzes, we determined the potential of (D) technology-enhanced learning objectives, (E) defined focus of medical learning content, and set requirements for (F) VR technology and usability.

D. *Learning objectives*

We focus on three learning objectives that were discussed and coordinated with the educational partners:

1. *Declarative knowledge:* Trainees can correctly identify, interpret and explain key symptoms of anaphylaxis from assessment using diagnostic algorithms, i.e., ABCDE-Scheme.
2. *Procedural knowledge:* Trainees can initiate technical diagnostics and advanced emergency medical measures.

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.

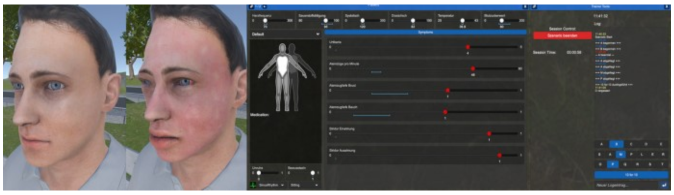

Fig. 4. Real-time graphics showing a healthy patient (left) besides a patient showing symptoms (center), as triggered using a trainer tool (right). Textures and mesh morphings for symptoms were precedural generated by using Substance Designer.

3. *Non-technical-skills:* Trainees can carry out care of the patient under consideration of success factors of collaborative teamwork.

E. *Medical learning content*

We (1) developed concrete pre-clinical case scenarios, (2) the feature space with patient's symptoms, and diagnostic and therapeutic actions with required medical equipment, and (3) the setup of the training scenario.

1) *Pre-clinical case scenario*

Developing concrete cases of anaphylaxis emerged as an interdisciplinary challenge: While medical educationalists prefer algorithm of user steps and predetermined outcomes, game developers require flow-charts that support multiple outcomes depending on interactive user dynamics. Development costs rise with complexity of such flow-charts, e.g., with number of outcomes and required amount of implementation of graphical symptoms, and of according treatment interactivity. It took multiple work meetings to develop a mutual understanding that led to scenario flow-charts (see Fig. 5) as a general tool that we can now apply for developing concrete case scenarios.

2) *Medical feature space*

Table 1 shows our resulting focus of features concerning the virtual patient and the diagnostic/therapeutic measures that trainees can perform. In addition, the development of a pathophysiological model for virtual patients was started. Fig. 4 depicts an example of procedurally generated visual symptoms,

TABLE I. FEATURES OF THE VIRTUAL PATIENT AND INTERACTION OPPORTUNITIES OF TRAINEES

Virtual Patient (clinical presentation. vital signs and parameters)	***Interaction opportunities of trainees within the VR-scenario***
• Dizziness and confusion • Urticaria, angioedema • Laryngeal edema and airway obstruction • Dyspnea, tachypnea, orthopnea, inspiratory and expiratory stridor, intercostal retractions • Cyanosis, mild to severe Hypo- or Hypertension • Tachycardia and tachyarrhythmia • Syncope • Postural change	• First survey according to the ABCDE-scheme • Intramuscular application and inhalation of epinephrine; Administration of oxygen and intravenous infusions • Patient re-positioning, remove patients clothing • Monitoring of pulse oximetry, ECG, blood pressure, temperature, sugar • Inspection of oropharyngeal region, auscultation of the lungs

which a trainer can adjust dynamically during training. Developing these symptoms was challenging, as it required quick feedback loops between designers, programmers and medical experts. We developed an online meeting environment that allowed all groups to participate in editing meetings.

3) *Training scenario setup and procedure*

Two trainees wearing head-mounted displays take on the roles of collaborating emergency paramedics. According to the 3 phases of medical simulation training, in the first phase of familiarization with the VR learning environment (up to 30 minutes), the trainees can try interaction possibilities, e.g., the use of diagnostic and therapeutic equipment, spatial navigation, and communication channels, etc. Trainees then enter a specific emergency scenario (training phase – 30 minutes) in which a virtual patient shows symptoms of severe anaphylaxis. Both trainees must apply systematic, guideline-based diagnostics (ABCDE scheme), therapy, and success factors in teamwork. An instructor (trainer) performs initiation and control of the scenario. She evaluates trainees' actions either in real-time on screen as well as in log-files generated for a subsequent de-briefing session. The software offers recording of the training so that trainees can retrospectively assess their behavior and actions from different perspectives (ego perspective, bird's-eye view). After training, debriefing takes around 15 minutes.

F. *VR technology and usability*

The primary identified goal for selecting VR hardware and for developing VR software is easy integration and maintenance at paramedic education sites. A first key requirement is the use of off-the-shelf equipment. We compared different VR headsets, primarily Oculus Rift CR1 and HTC VICE, and selected the latter for the first prototype based on its advantages in 3D interaction, walk-in volume and support of multiple users in a shared tracked volume, directly mimicking a training scenario. Disadvantages compared to the Oculus were a lower legibility of writing related to lens/display design and poorer wearer ergonomics. A second key requirement is the optimization of usability in software. We analyzed more than 30 VR games for ways of navigation, interaction, and visualization. Most VR games were aquired/purchased via steam for the HTC VIVE like "Surgeon Simulator VR: Meet The Medic", "Job Simulator", "POLLEN", "Tilt Brush", "Windlands" and more recent games like "The Body VR: Jouney Inside a Cell" or "Vacate the Room". We also analysed games on the Playstaion 4 with the PSVR-Headset like "Fantastic Contraption" and "Batman: Arkham VR". Being aware of the history of 3D interaction in VR with a large variety of methods [20] we were looking for evolving standards users might rely on. Our findings are that there are no standards, yet, so VR systems must be very careful in teaching how to use them.

1) *Navigation*

The HTC VIVE tracking system offers sufficient shared physical space to two users. In our current scenario, the interaction scope is bounded to the provided physical space so that no other navigation approaches are necessary, besides the natural movements of the players. In the future, we need to allow single users to leave the limited virtual space, e.g., to virtually walk to the ambulance car to fetch additional equipment. We

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.

hence evaluate alternative continuous navigation approaches where the player is moving the avatar while standing still. One major side effect is motion sickness, which can be mitigated by using teleport, visual extensions, reducing speed or avoiding strong acceleration [21]. Teleport navigation may reduce motion sickness, with disadvantages in a less immersive movement, or possible disorientation, and optimization potential in teleport transitions, e.g., by showing animated zooms, fade-to-black, or via orientation volumes. De-coupling the volumes for one player in a co-located multi-user volume requires visualization of the current physical and/or virtual positions of the other user/player. Another future challenge is how to re-match virtual and physical volumes after de-coupling through user redirection.

2) Interaction

A recent list of VR interaction techniques can be found in [22] that can be roughly divided into virtual hand and virtual pointer techniques. The virtual hand can select an object by coming close to it, a trigger pairs orientation of the hand with that of the object. The pointer is a line reaching out from a user's hand position or controlled via gaze direction. It can be used to reach distant objects. We propose to use virtual hand in general for virtual content and the pointer for selecting menus.

To model the virtual scenario as realistic as possible, we implemented medical cases and instruments in their real shape and proportion. Users can pick items by putting the virtual hand into a case and navigating through a superimposed virtual menu (see Fig. 6). One main challenge in a learning environment is that such menus can prime a user about what she may do or not. However, real paramedics cannot rely on such mental support. A second challenge is that the VIVE controller requires a hand posture that does not match with more fine grain interactions, such as injecting a syringe. Haptics are clearly missing here. Third, items are dropped occasionally and thus fall to the ground, mostly for reasons of erroneous interaction. A good solution is to let items float for 3-5 seconds until being dropped slowly. This allows a user to re-grab them.

We also evaluated additional inventory design concepts in [23] where paramedics can store, access and manage their medical instruments via a metaphoric belt or an abstract menu-based tablet. In an evaluation, 24 paramedic trainees rated utility of both concepts rather high. In a multi-user scenario, seeing what items another user currently owns can support context awareness.

3) Visualization

Volante et al. [24] compared the effects of three different visualisations of a virtual patient (realistic vs. cartoon like vs. sketch like) on potential caregivers in a clinical patient scenario, indicating that visually less realistic avatars can evoke strong feelings. We therefore apply a moderately detailed realistic art style in general. Visual body symptoms—realized through procedural texture blending—are implemented as realistic as possible to support fine grain severity diagnosis (see Fig. 4). Environmental objects or medical instruments are designed in a clean, functional manner to foster focus on training procedures (see Fig. 6).

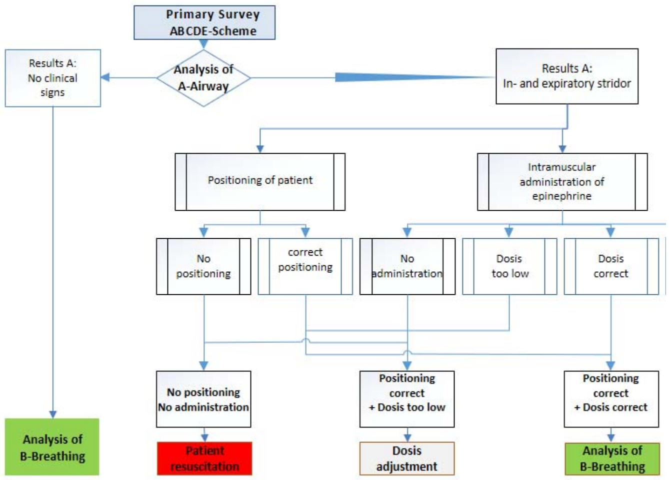

Fig. 5. Basic diagnostic and therapeutic measures according to the ABCDE-Scheme, excerpt for A = Airway. The graph shows a concrete paramedical case as interactive scenario, i.e.,how user reactions lead to different outcomes.

The current visualisation of player avatars is limited to the head and to the hands, i.e., the only limbs tracked by HTC VIVE Lighthouse system. The other body parts can be tracked using additional trackers and/or by applying inverse kinematics. First results show that attaching additional trackers can be a cumbersome procedure and that bad signal and virtual body modelling often leads to effects that break immersion. Especially, prone body poses, which occur quite often in our scenario, cause interbody-occlusion which damps the signal significantly. Another attempt was to connect head and hands of the playing avatars with elastic tubes to imply cohesiveness. User reactions are rather negative, pointing out unnatural effects and a request for occlusion through body mass. In summary, effective multi-user VR requires more elaborate solutions for this problem space.

4) Multi-user tasks

Our current setting involves three users: Two trainees encounter each other as treating paramedics and one trainer (a medical specialist) can operate on the scenario by influencing the patient's symptoms. The paramedics work as a team, communicating, supervising and helping each other by giving hints and handing out instruments. The trainer controls patient health and physiology or provides feedback on anamnesis. We identified emotionalization as a key potential in multi-user situations. A lack of gaze animation or facial mimics of paramedics and the patient becomes obvious once you use the simulation. However, a first evaluation on the impact of eye tracking on co-located VR situation reported no difference in perceived quality of conversation between random gaze and eye-tracking-based gaze animations [25].

G. Development Process

After the pilot studies and the concept phase where we found focus in medical procedures and created cases, we first established a virtual training environment as common meeting place. The technology is based on TriCAT Spaces commercial remote meeting software. It allows multiple users to enter a

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.

shared VE using desktop PCs or VR platforms. We used the training environment also as a virtual meeting place to evaluate the latest development and for interdisciplinary Scrum meetings.

IV. Evaluation

A. Setup and preparation

Based on the learning objectives and on models of learning in VR [26], we conducted a user study on the simulation prototype. As metrics, we collected data on presence experience and usability. We tested training design and outcomes with 24 trainees (♂ = 19, ♀ = 5, mean age = 23.3) in both paramedic-training institutions. All 24 trainees completed the three phases (familiarization, scenario, and debriefing) as described above. As preparation, we had previously trained the trainers in three sessions, introducing them to the current state of prototype development and the use of the VR as a training method.

B. Hypothesis and metrics

1) Hypothesis

We hypothesize, that high usability (interaction experience) contributes to a high presence experience (as a precondition of learning experience). Parameters that were evaluated as part of a bivariate correlation analyses were the variables (mean scores) of the usability and the presence questionnaire. The learning experience was analyzed with descriptive statistic, using the Training Evaluation Inventory. Furthermore, focused interviews were conducted and analyzed.

2) Presence

We obtained presence measures from subjective rating scales, using the Igroup Presence Questionnaire (IPQ). IPQ measures the sense of presence experienced in a VE. It has three subscales with a maximum mean score of 6 and one additional general item. The three subscales are: (1) Spatial Presence - the sense of being physically present in the VE. (2) Involvement - measuring the attention devoted to the VE and the involvement experienced, and (3) Experienced Realism - measuring the subjective experience of realism in the VE. The additional general item assesses the general "sense of being there", with an especially strong loading on spatial presence [27].

3) Usability

The System Usability Scale (SUS) [28] is a simple and technology-independent questionnaire to assess usability of a system. The SUS is an established method for the quantitative analysis of the usability. It includes 10 Likert-scaled items.

4) Learning Experience

The TEI (Training Evaluation Inventory) is an instrument for evaluating learning experience in trainings. The questionnaire can be included in both, formative and summative, training evaluation. The ten scales of the TEI cover training-relevant outcome dimensions as well as aspects of training design [29]. Kirkpatrick's (1998) influential hierarchical evaluation model with the four levels "reactions", "learning", "behavior" and "results" formed the basis for the conception of the outcome dimensions subscale (max. dimensions score value M = 5.0). The training design focuses on the aspects of a training that support the participants in learning and in transfer of what they have learned into their daily work. The dimensions of the training design are based on Merrill's principles of instructional learning (2002) (max. dimension score value M = 5).

C. Results

1) Presence Experience

Table II shows the sample mean scores for the general item and the three subscales. The scores indicate a high sense of overall and spatial presence, while experienced involvement and realism scored on the medium range.

To better interpret the subscale values, we conducted focused interviews with the 24 participants. Results indicate that high presence scores emerge early in the VR-training. However, there are still experiences of “breaks in presence” (BIP) as participants are bound to two ways of communication: (1) with the team partner (trainee) using headphones ("in the virtual world") and (2) directly with the instructor ("in the real world"). Spatial navigation in VE is also described as difficult. In addition to the interference caused by the headset-cables, the incomplete graphical representation of co-worker’s avatar is reportedly irritating. Since the strength of multi-user VR simulation training lies in team-based work or the promotion of so-called non-technical skills, these aspects (interaction, communication and navigation) should face significant improvement.

2) Usability/Interaction Experience

The total mean score (*M*) of the SUS was 63.95 (*SD* 12.96; *R* 32.5–87.5). Is such a score sufficient to say, that the prototype

Fig. 6. A virtual patient can be examined, e.g., by opening the mouth or taking the pulse (left and center-left). The environment shows the patient in context with medical instruments in use and a floating overlay menu (center-right); the available medical instruments as implemented (right).

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.

TABLE II. SAMPLE MEAN SCORE FOR IPQ-SUBSCALES

IPQ-Subscale	*Overall experienced presence*	*Spatial presence*	*Involvement*	*Experienced Realism*
M	5.04	4.45	3.45	3.16
SD	1.09	0.99	1.5	1.01

TABLE III. SUS PERCENTAGE DISTRIBUTION ON THE GRADE SCALE

Grade Scale	*F (0-60)*	*D (60-70)*	*C (70-80)*	*B (80-90)*	*A (>90)*
%	29.2%	37.5%	25.0%	8.3%	0.0%

is usable? We examined the individual users' SUS scale values regarding their statements in the focused interviews. Users with scale values in the lower quartile (*R* 32.5–50.0) particularly had problems with real body movement, caused by headset cables and by wearing the headset. We found medium to very strong correlations between the SUS scale values and single subscales of IPQ-presence questionnaire (r=.59 [SUS/Overall experienced presence], r=.63 [SUS/Spatial presence], r=.48 [SUS/Involvement], r=.73 [SUS/Experienced Realism]. Table III shows the percentage distribution of single scale scores based on the grade scale, which Bangor et al. propose as interpretation aid [30].

3) *Learning Experience*

The results of the TEI-Questionnaire show above-average values for all subscales, respectively for the two dimensions (Training Outcome Dimensions: M = 3.8 [SD 0.37]; Training Design Dimensions: M = 3.4 [SD 0.36]). The scale values of both dimensions show a very strong correlation (r=.80). In our study, the training design values are slightly lower than the training outcome values. The training design dimensions serve as antecedents of training outcomes.

4) *User comments*

Most users commented enthusiastically about their experiences, how deep they felt inside the scenario, e.g., "like with no other training medium ever". Multiple users experienced warm temperatures reportedly due to the summer lake scenario of the session, albeit the training took place in cold October. Most reported usability issues related to the wired connection of the head-set, the visual quality of the head-set, or the sound issues, communicating with trainees and trainers using different media.

V. DISCUSSION

The correlations formulated in the hypothesis can be confirmed by the results of the user study: The noted usability issues (see above) contribute to "breaks in presence" experience and extraneous cognitive load (split attention effect). This in turn seems to limit results to above-average values in the perceived learning effectiveness. Furthermore, the results of the TEI questionnaire also show that trainers and trainees must be even more actively involved in the ongoing development and implementation process. However, the relatively high scores for the training outcome dimensions shows that trainees rate the VR-simulation as a training method with a great impact on the development of professional skills.

TABLE IV. VR DESIGN ISSUES FOR TRAINING SIMULATIONS

Area	*Issue*	*Proposed solutions*
Navigation	In general	Use tracked volume for focused scenario
	Cyber sickness	Teleport, visual extensions, slow speed
	De-/re-coupling of sharing virtual/ real space	Visualization of partner avatar location in real volume
Interaction	In general	Virtual hand for items, virtual pointer for menus
	Context-aware inventory	Virtual belt
	Menus bias user decision making	Pure audio interfaces
	Fine interactions	Different input devices or gloves?
	Missing haptics	Visualize haptic experiences
	Lost dropped items	Let loose items temporarily float in air
Visualization	Realism vs. comic visuals	Not highest production value, but medical details need to be adequate
	Multi-user awareness	Full-body tracking and visualization, abstract solutions, ghosts
Multi-user	Emotionalization	Use eye tracking for gaze animation, real-time animations of mimics
	Communication	Support different channels between trainees, and with trainers

We identified several usability issues. We received no negative comments on the medical content. The visual style (realistic but not too detailed) and quality of symptoms worked out fine. Also, from a current technical point of view, we cannot sufficiently provide a full simulation of body health and physiological reaction, offer all kinds of fine-motor interactions at all body points, simulate haptics (e.g., cables, small environments, organic elasticity). But having a trainer control physiology and health as reactions to the trainees' actions in a Wizard-of-Oz-like situation appears a good solution.

The described interdisciplinary development process has strongly contributed to these results. The implemented Scrum process was supportive in that it provided regular meetings. But we could not maintain full agile methodology in an interdisciplinary setup. In the future, we will switch to longer development phases (>4 weeks) with active direct communication channels between developers and technical experts, with more sub-milestones throughout the process. During the preceding development phase, we identified a set of open issues of VR technology, that needs to be addressed in research and development. Table IV lists these issues.

VI. CONCLUSIONS AND FUTURE WORK

This paper showcases the interdisciplinary and iterative process of developing EPICSAVE, a virtual reality training simulation for paramedics. The results of an evaluation show that a positive learning experience depends on a high presence experience which gains from high interactivity and VR usability. Especially usability in VR is an issue as there are no standards, yet. Such rough factors in our VR-prototype, which lead to "breaks in presence" experience and cognitive load (e.g., communication and navigation in VE, wired head-sets). Our development case offers a detailed report how close interdisciplinary collaboration and the iterative workflow

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.

contribute to medical focus and reasonable production performance creating novel VR-based training media that also incorporate new didactic concepts. We identified a list of open design issues that we will tackle in future work and strongly encourage other researchers to join us doing so. In general, to contribute to a better training outcome, we must improve integration of VR in training facilities and learning impact for more target groups. Our next approach will examine how serious gaming can contribute to motivational aspects and learning effect beyond the simulation level demonstrated here.

ACKNOWLEDGMENT

This work was carried out within the project EPICSAVE funded by the German Federal Ministry of Education and Research (BMBF) and by the European Union, European Social Fonds (ESF), FKZ 01PD15004). Besides the authors, the following people have contributed to this work: Markus Herkersdorf, Konstantin Wegner, Frederik Schneider, Markus Neuberger, Andreas Franke, Claus Kemp, Johannes Pranghofer, Liubov Gorodilova, Eva Blum, Benjamin Roth, Leonard Flock, Sven Seele, Helmut Buhler and Rainer Herpers.

REFERENCES

[1] B. Urban, M. Lazarovici, B. Sandmeyer. “Simulation in medicine – inpatient simulation”, Simulation in der Notfallmedizin – Stationäre Simulation, M. St. Pierre, G. Breuer, (Eds.), “Simulation in medicine”, Simulation in der Medizin. Springer, Berlin Heidelberg, 2013, pp. 231–248.

[2] F. E. R. Simons, M. Ebisawa, M. Sanches-Borges, B. Y. Thong, M. Worm, L. Kase Tanno, et al., “2015 update of the evidence base: World Allergy Organization anaphylaxis guidelines”, World Allergy Organization Journal 2015; 32 (8), pp. 1–16.

[3] O. Meyer, “Simulators don´t teach – Process of Learning and Simulation”, M. St. Pierre, G. Breuer, (Eds.), “Simulation in medicine”, Simulation in der Medizin. Springer, Berlin Heidelberg, 2013, pp. 55–70.

[4] S. De Ribaupierre, B. Kapralos, F. Haji, E. Stroulia, A. Dubrowski, R. Eagleson, “Healthcare Training Enhancement Through Virtual Reality and Serious Games”, M. Ma, L. C. Jain, P. Anderson, (Eds), “Virtual, Augmented Reality and Serious Games for Healthcare 1”, Springer, Berlin Heidelberg, 2014, pp. 9–28.

[5] R. Dörner, S. Göbel, W. Effelsberg, J. Wiemeyer (Eds.), “Serious Games. Foundations, Concepts and Practice“, Springer International Publishing, Switzerland, 2016.

[6] M. Kerres, “Media Didactics: Design and Development media-supported Learning”, Mediendidaktik: Konzeption und Entwicklung mediengestützter Lernangebote, Oldenbourg Wissenschaftsverlag, München, 2013, pp. 241–255.

[7] R. Ghanbarzadeh, A. H. Ghapanchi, M. Blumenstein, A. Talaei-Khoei, “A Decade of Research on the Use of Three-Dimensional Virtual Worlds in Health Care: A Systematic Literature Review”, Journal of Medical Internet Research 2014, 16 (2), e47, pp. 1–20.

[8] A. Correia, B. Fonseca, H. Paredes, P. Martins, L. Morgando, “Computer-Simulated 3D Virtual Environments in Collaborative Learning and Training: Meta-Review, Refinement, and Roadmap”, Y. Sivan, (Eds.), “Handbook on 3D3C Platforms, Progress in IS”, Springer International Publishing, Switzerland, 2016, pp. 403–440.

[9] F. Consorti, R. Mancuso, M. Nocioni, A. Piccolo, “Effecacy of virtual patients in medical education: A meta-analysis of randomized studies”, Computers & Education 2012, 59 (3), pp. 1001–1008.

[10] Z. Merchant, E. T. Goetz, L. Cifuentes, W. Keeney-Kennicutt, T. J. Davis, “Effectiveness of virtual reality-based instruction on students` learning outcomes in K-12 and higher education: A meta-analysis”, Computers & Education, 2014, 70, pp. 29–40.

[11] C. D. Flores, P. Barros. S. Cazella, M. R. Bez, "Leveraging the learning process in health through clinical cases simulator." Serious Games and Applications for Health (SeGAH), 2013 IEEE 2nd International Conference on. IEEE, 2013.

[12] M. A. Zielke, D. Zakhidov, G. Hardee, L. Evans, S. Lenox, N. Orr, D. Fino, G. Mathialagan, "Developing Virtual Patients with VR/AR for a natural user interface in medical teaching." Serious Games and Applications for Health (SeGAH), 2017 IEEE 5th International Conference on. IEEE, 2017.

[13] E. A. Boyle, T. Hainey, T. M. Connolly, G. Gray, J. Earp, M. Ott, et al., “An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games”, Computers & Education, 2016, 64 (2), pp. 178–192

[14] P. Wouters, C. van Nimwegen, H. van Oostendorp, E. E. van der Spek, “A Meta-Analysis of the Cognitive and Motivational Effects of Serious Games”, Journal of Educational Psychology, 2013, 105 (2), pp. 249–265.

[15] R. Wang, S. Jr. DeMaria, A. Goldberg, D. Katz, “A Systematic Review of Serious Games in Training Health Care Professionals”, Simul Healthc, 2016, 11 (1), pp. 41–51.

[16] R. M. de Lima, A. de Medeiros Santos, F. M. M. Neto, A. F. de Sousa Neto, F. C. P. Leão, F. T. de Macedo, A. M. de Paula Canuto, "A 3D Serious Game for Medical Students Training in Clinical Cases" Serious Games and Applications for Health (SeGAH), 2016 IEEE International Conference on. IEEE, 2016.

[17] D. Kolb, A. Kolb; “The Kolb Learning Style Inventory 4.0: Guide to Theory, Psychometrics, Research & Ablications”, 2013.

[18] G. F. Tondello, R. R. Wehbe, L. Diamond, M. Busch, A. Marczewski, L. E. Nacke, “The Gamification User Types Hexad Scale“, CHI PLAY ’16 Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play, 2016, pp. 229–243.

[19] D. A. Sclar, P. L. Lieberman, “Anaphylaxis: Underdiagnosed, Underreportet, and Undertreated“, The American Journal of Medicine 2014, 127 (1), pp. S1–S5.

[20] D. A. Bowman, E. Kruijff, J. J. LaViola, I. Poupyrev, “3D User Interfaces–Theory and Practice“, Pearson Education, Boston, 2005.

[21] M.L. Ibáñez, F. Peinado, “Walking in VR: Measuring Presence and Simulator Sickness in First-Person Virtual Reality Games, 2016, Palmieri, O., Full Speed Flying in VR! The R&D behind Eagle Flight, 2016, Oculus VR, Oculus Best Practices, 2016

[22] F. Argelaguet, C. Andujar, “A Survey of 3D Object Selection Techniques for Virtual Environments”, Computers & Graphics, 2013, 37 (3), pp. 121–136.

[23] K. Wegner, S. Seele, H. Buhler, S. Misztal, R. Herpers, J. Schild, 2017. “Comparison of Two Inventory Design Concepts in a Collaborative Virtual Reality Serious Game”. In CHI PLAY '17 Extended Abstracts. ACM, New York, NY, USA, 2017, pp. 323–329.

[24] M. Volante, S. V. Babu, H. Chaturvedi, N. Newsome, E. Ebrahimi, T. Roy, S. B. Daily, and T. Fasolino. "Effects of virtual human appearance fidelity on emotion contagion in affective inter-personal simulations." IEEE transactions on visualization and computer graphics 22.4, 2016, pp. 1326–1335.

[25] S. Seele, S. Misztal, H. Buhler, R.Herpers, J. Schild, “Here's Looking At You Anyway!: How Important is Realistic Gaze Behavior in Co-located Social Virtual Reality Games?”, Proceedings of the Annual Symposium on Computer-Human Interaction in Play CHI PLAY '17, ACM, 2017, pp. 531–540.

[26] M. C. Salzman, C. Dede, R. B. Loftin, J. Chen, “A Model for Understanding How Virtual Reality Aids Complex Conceptual Learning”, Presence 1999, 8 (3), pp. 293–316.

[27] T. W. Schubert, “The sense of presence in virtual environments: A three-component scale measuring spatial presence, involement, and realness”, Zeitschrift für Medienpsychologie, 2003, 15 (2), pp. 69–71.

[28] J. Broke, “SUS – A quick and dirty usability scale”, Usabitlity Evaluation in Industry, Taylor and Francis, London, 1986, http://www.usabilitynet.org/trump/documents/Suschapt.doc

[29] S. Ritzmann, V. Hagemann, A. Kluge, “The Training Evaluation Inventory (TEI) – Evaluation of Training Design and Measurement of Training Outcomes for Predicting Training Success”, Vocations and Learning 2014, 7 (1), pp. 41–73.

[30] A. Bangor, P. Kortum, J. Miller, “Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale”, Journal of Usability Studies 2009, 4 (3), pp. 114–123.

Authorized licensed use limited to: University of Southern Denmark. Downloaded on December 01,2025 at 08:22:18 UTC from IEEE Xplore. Restrictions apply.