Integrated Learner Assessment for Readiness Tracking within Virtual Reality Medical Simulation

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ABSTRACT

Longitudinal learning performance, assessment, and readiness tracking are essential components for maintaining the high standard of capability required of DOD medical personnel. However, different learning modalities for medical training make standardization and performance tracking difficult. In this work, we report on our development of a virtual assessment capability for medical simulation training using existing standardized assessment tools and its integration into a pre-existing human performance tracking system to enable the future generation of novel insights into human performance, assessment, and readiness tracking.

The Pararescue Medical Skills Certification Scoring Guide from Air Force Instruction 10-3502 was selected as the assessment instrument for this project, and the appropriate assessable items were selected for integration into the medical simulation system's moderator tool. Additionally, an application programming interface (API) was identified for the performance tracking system to allow integration with the longitudinal readiness tracking system.

The specified assessment tool was successfully implemented into the medical simulation system moderator tool. Major categories assessed included initial assessment tasks, recording of vitals and patient history, secondary assessment tasks, scenario-dependent tertiary tasks, Mechanism, Injuries, Signs and Symptoms, and Treatments (MIST) reporting, and specific knowledge assessment of protocols. Assessments were enabled on a per-learner basis, and the system API was used to enable upload of learner assessments, which then integrated assessments into the overall data analysis and tracking system. This was then integrated into a Tactical Combat Casualty Care (TCCC)-based medical simulation scenario proof-of-concept curriculum discussed in a separate report.

The resulting capability then underwent initial testing and evaluation during training exercises by Pararescuemen and combat controllers at Hurlburt Field Air Force Base. Initial acceptance testing demonstrated the practical usability of the assessment scoring system by training facilitators, and a successful upload capability to the performance tracking system. Based on this result, further testing and evaluation is planned across an expanded trainee set.

ABOUT THE AUTHORS

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Talia L. Weiss directs SimX's scenario and training production program, overseeing the company's production pipeline with more than 150 scenarios. She has managed multiple platform enhancement and new curriculum projects, including nursing, TCCC, and aeromedical transport. Talia has experience in medical visualization, digital media, and healthcare management consulting, and served as the manager of the Stanford Virtual Human Interaction Lab.

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INTRODUCTION

Longitudinal learner assessment and readiness tracking is an essential component of maintaining the high standard of capability required of the DOD's medical personnel. As the medical community has transitioned to the high-reliability organizational model, the need for training and a preoccupation with failure serve as high-visibility areas for potential improvement (Veazie et al., 2022). Medical simulation has been identified as an effective addition to the medical training toolkit (Kennedy et al., 2014; Lorello et al., 2014). Building on the success of these previous endeavors, the Virtual Advancement of Learning for Operational Readiness (VALOR) program, funded and led by the United States Air Force, has the mission of increasing combat readiness across multi-domain operations. Its goals are to improve realism, increase flexibility, and reduce the cost of operational medical training for elite military personnel, and simulation training has played an important role in accomplishing this goal. We detail a process through which high-yield military case content was created, critical action assessment tracking was made possible, immediate and longitudinal feedback was provided, and training history was recorded for mission readiness tracking purposes. This information was then directly integrated into a system that already considers human factors including physical fitness, overall health, and nutrition. The additional insight provided adds color to the overall picture of an Airman, delivers cost-effective mission readiness training, and allows for the identification of areas of weakness, strengths, and training trends.

BACKGROUND

Simulation in the Military

Simulation serves as a vital component that many military groups utilize to keep skills sharp and identify potential pitfalls and shortcomings before facing these challenges first-hand. One of the most well-known training programs and guidelines established by the military came in the form of Tactical Combat Casualty Care (TCCC), initially utilized by the Naval Special Warfare community (Butler, 2017). TCCC guidelines were initially formed to address the observation of a large number of potentially survivable injuries due to extremity hemorrhage. Given the initial popularity of this narrow scope, it grew to include all major types of battlefield trauma. Other early first steps taken by the US military medical community to support simulation training came in 1999 after the data collected during the Persian Gulf War demonstrated no change from previous conflicts in the number of combat wound-related deaths (25%). As a response, the US Army focused on providing better medical care and increased training for combat medics (Deering et al., 2012). This expanded training included simulation as a core element. Subsequent encounters saw this number successfully decrease to 10% in the face of increased trauma rates caused by advances in wartime weaponry.

Despite an improvement in the overall mortality rate, the number of deaths considered preventable remained steady at 10%. To combat this, the US Army created the Medical Simulation Training Center (MSTC) program (McCarthy, 2003). The MSTC program arose as a response to data published in 2005 showing that the number of preventable battlefield deaths had not changed significantly between the Vietnam and the Persian Gulf conflicts despite advances in training. It was postulated that the lack of improvement may have been due to the lack of standardization of training protocols and the sustainment of necessary skills. The MSTC program focused primarily on the training of combat medics, that is, those present most immediately for battlefield injuries, and taught the newly developed TCCC curriculum. At its peak during the Iraqi conflict, the total number of trainees per year at designated MSTC sites totaled more than 120,000 individuals.

It was soon realized that this training would also be beneficial to nurses and physicians. To this end, the Army created the Central Simulation Committee in 2007 intending to standardize Army Graduate Medical Education Simulation training (Deering et al., 2012). Other military branches followed suit by creating programs such as the Air Force Medical Modeling and Simulation Program (AFMMAST), and the Navy made strides in standardization as well.

Types of Simulation Training

Multiple modalities can be included under the umbrella of simulation, many of which have demonstrated improvements in learner knowledge as well as, albeit less robustly, patient outcomes (Zendejas et al., 2013). The most common types of simulation training utilized involve some combination of real-world equipment and facsimile. Whatever the method implemented, certain core components are required to ensure maximum benefit can be obtained from simulation training programs (McGaghie et al., 2010). These include (i) feedback; (ii) deliberate practice; (iii) curriculum integration; (iv) outcome measurement; (v) simulation fidelity; (vi) skill acquisition and maintenance; (vii) mastery learning; (viii) transfer to practice; (ix) team training; (x) high-stakes testing; (xi) instructor training, and (xii) educational and professional context.

While effective, one cannot understate the cost in time, space, and man-hours required for traditional simulation training. Data are currently limited, as most studies on simulation focus on increased knowledge and patient outcomes. Data published regarding the Penn Surgical Simulation Center, which included a 4-week simulation-based training program, estimated costs of 4.2$ million in total setup costs, $476,000 in annual operational expenses, with an annual cost per trainee of $12,700 (Danzer et al., 2011). These numbers primarily reflect personnel costs and the creation/redesign of available simulation areas but can also be attributed to training space requirements as well as consumable equipment utilized.

Virtual Reality Training

The subset of virtual reality (VR) simulation training is relatively new, with promising initial results regarding standardization, efficacy, and cost-effectiveness. The methodology involves placing the user in a head-mounted display which allows for a more completely immersive experience. As the formation of new memories is strongly linked to the sensation of "being there," (Makowski et al., 2017) VR brings to the table a sense of realism difficult (and costly) to recreate in traditional environments.

Many groups, particularly those in the military, see the minimal space requirements of VR training as a significant advantage. VR training typically requires less space for equipment storage, scenario creation, and breakdown, as compared to traditional training methods such as mannequin-based or task-trainer-based scenarios. In the military specifically, where travel and high mobility are often required depending on the mission, a single headset can offer training with a fraction of the footprint that manikin-based or task-trainer-based scenarios would require. In addition, the ability to train with members of a tactical unit who may live hundreds of miles away provides other large cost savings while allowing for more frequent, less logistically strenuous training opportunities.

Where VR training has shone academically is in clinical decision-making skills. One of the most important identified factors used in high-fidelity simulation training that led to effective learning is repetitive practice (Issenberg et al., 2005). This is much more easily facilitated using VR-based training, which allows multiple playthroughs of the same scenario without the need for scene breakdown/recreation and can be guaranteed to be identical from one session to the next.

Importance of Feedback and Assessment Tracking

The most important aspect of simulation required to attain the most effective learning is feedback, followed closely by curriculum integration (Issenberg et al., 2005). To provide feedback, progress and accurate assessment tracking of each scenario must be recorded to allow effective debriefing. Equally important is the ability to review longitudinal progression in a standardized fashion. This allows a search for common trends in terms of potential deficiencies and identification of areas of improvement. Different learning modalities for medical simulation training often require a variety of different assessment tools and measures, which complicate the longitudinal assessment of individual warfighter readiness for specific competencies. This individualized assessment (and the communication of this feedback to the learner) is essential to identify and provide additional support training to address potential weaknesses in mission readiness.

Military Readiness Tracking

Readiness planning and tracking are core components of maintaining the world's premiere military force. Different groups in the armed services have attempted to track and attain readiness goals through a variety of systems, with varying levels of success. The US Air Force has remained one of the leaders among its peers largely thanks to its efforts in the standardization and digitalization of available data (Brauner et al., 2012). Other branches have followed suit with efforts including the Limited Duty Sailor and Marine Assessment of Readiness Tracking System (SMART), Readiness Analytics and Visualization Environment (RAVEN), and the Force Readiness Analytics Group (FRAG). These programs share a common theme: the belief that only through more complete data collection and standardization can current readiness be successfully monitored, analyzed, and improved.

METHODS

The groundwork laid for this project came from prior research efforts between SimX and the United States Air Force, which was focused on identifying training requirements that would most benefit from a VR medical simulation solution. Drawing on results from these projects allowed for the creation of an extremely targeted approach to the creation of a novel, integrated learning program.

Specification Phase

In the specification phase, the learner population was first identified. Pararescue personnel have a unique scope of practice in the military setting that allows them to perform procedures and tasks that are typically reserved for those with higher levels of training. This is driven by necessity, as they maintain responsibility for critically injured patients for the first minutes (to hours) of care, a time during which many outcomes are already decided. The elements of care required include the skills used by medical technicians, nurses, respiratory technicians, and physicians. As this is a group that is expected to perform complex tasks under pressure with relatively less time in a training environment, the partnership seemed mutually beneficial to both parties. By utilizing VR training, Pararescue personnel were able to run through many complex scenarios in a relatively short amount of time. In addition, their results were able to be recorded and added to data detailing their mission readiness status. Using such a pluripotent group with such wide-ranging skills also suggests feasibility with other similar groups, if successful.

To allow for the most useful feedback to be compiled, a clinical educator working group was formed. It consisted of the principal investigator, emergency physicians, USAF Pararescuemen, and a USAF Pararescue Medical Director. The Pararescue Medical Skills Certification Scoring Guide from Air Force Instruction 10-3502 was selected as the assessment instrument for this project, as it serves already as a standardized measure of Pararescue personnel medical skills (U.S. Air Force, 2012). Commonly identified areas for potential improvement were selected that included extremity hemorrhage, airway obstruction, and tension pneumothorax, as well as other patterns of TCCC-related injury patterns. These scenarios were then integrated into the Pararescue training program.

The importance of assessment tracking, feedback (both immediate and longitudinal), and integration into the curriculum was discussed thoroughly. To fulfill these crucial requirements, the simulation case moderator was given additional functionality. These included (1) the ability to record and rewatch trainings, allowing for more detailed feedback, (2) the addition of the BATDOK system which allowed documenting of all performed interventions, and (3) the ability to generate an upload-compatible report, which could be uploaded directly to the existing performance tracking system.

Case Curriculum and Creation

TCCC training, as described above, has been utilized for many years to teach military medical personnel battlefield-centric medical care (Butler, 2010). It remains a critical piece of required military training prior to deployment, covers a wide breadth of high-yield topics, and already has a tracking system in place. As such, it was chosen as the curriculum for which to integrate the new functionality. The chosen cases were identified as having a greater clinical benefit based on military medical subject matter experts.

The scenarios, environmental overviews, and performance tracking metrics were then designed in a three-step manner. In the first step, a content outline request was sent to US Air Force stakeholders detailing their goals and learning objectives for the cases, in addition to the desire for general flow for case progression. The stakeholders completed these forms, which were reviewed by a member of the SimX Medical Oversight Board (MOB), a physician with specific training in the area of interest, for further review and clarification. The MOB member expanded on the details and requests of the collaborators and created a training that maximized the learning goals desired while remaining within the constraints of what is feasible in a VR setting. All necessary tools, settings, and patient/non-playable character information required for the case were explicitly stated in the concept outline. Once completed, this document was also presented to the collaborator for approval and review. Any specific changes requested by the collaborator were addressed through iterative feedback until all requests/recommendations were fulfilled.

Once the collaborator approved the proposed case flow, concept, and tracking metrics/critical actions, Step 2 involved internal collaboration between the MOB and VR production specialists. This process involved detailing specific case layouts, available tools, and design and functionality. If necessary, specific patient information was scoped and developed to align with learning objectives. Once both parties reached an agreement on the case specifications, the process entered Step 3, in which a VR production specialist distilled the information into a standardized tabular data document. This document was the source that case developers use to implement the specific case. For cases in which new tools were required, VR specialists worked with members of the Quality Assurance (QA) team to design and test the tools for the scope of their expected functionality. Following the generation of all tools and assets, the documentation was distributed to the engineering team, who then developed an initial version of the case. Once the case was developed, the internal QA team met with the MOB members to test each scenario for content, case flow, and bugs. Once the cases were in a state deemed complete, they were returned to the collaborator for approval. Any changes recommended were then discussed and addressed before final case sign-off.

Once the cases were complete, they were accessible by the collaborator and could be run at any time, as many times as desired, for the duration of their contract. The tools required include a laptop or computer, a 12x12 or 20x20 foot area space (depending on the case), as well as a VR headset. After completion of said scenarios and testing by US Air Force personnel, the need for standardization with their currently existing readiness tracking system was noted, as well as a request for direct recording of each session for playback learning purposes. Then these tools were created and implemented into each scenario.

System Integration and Standardization

The Pararescue Medical Skills Certification Scoring Guide from Air Force Instruction 10-3502 was selected as the assessment instrument for this project, and appropriate assessable items were selected for integration into the medical simulation system's moderator tool. These included initial assessment tasks in the MARCH algorithm (massive hemorrhage, airway, respiration, circulation, head injury/hypothermia) algorithm, vitals and secondary assessment tasks via the PAWS algorithm (pain, antibiotics, wounds, splinting) algorithm, appropriate scenario-dependent tertiary tasks (packaging for CASEVAC and MIST reporting, HHHITMMAN for extended care), and specific knowledge assessment of protocols (such as shock, traumatic brain injury, acute abdomen, intubation). Assessments were enabled on a per-learner basis. Additionally, an application programming interface (API) was to enable integration with the longitudinal readiness tracking system.

The pre-existing performance tracking system was developed to address the need for longitudinal evaluation and tracking in the context of training for fitness and optimized nutrition. However, many of the same factors that influence fitness levels also influence learning. Thus, it is logical to integrate learner performance with the other measured factors to enable improved insights. The system API was used to allow the upload of learner assessments, which then integrated the assessments into the overall data analysis and tracking system. The resulting capability was then integrated into a TCCC-based medical simulation scenario curriculum discussed in a separate report.

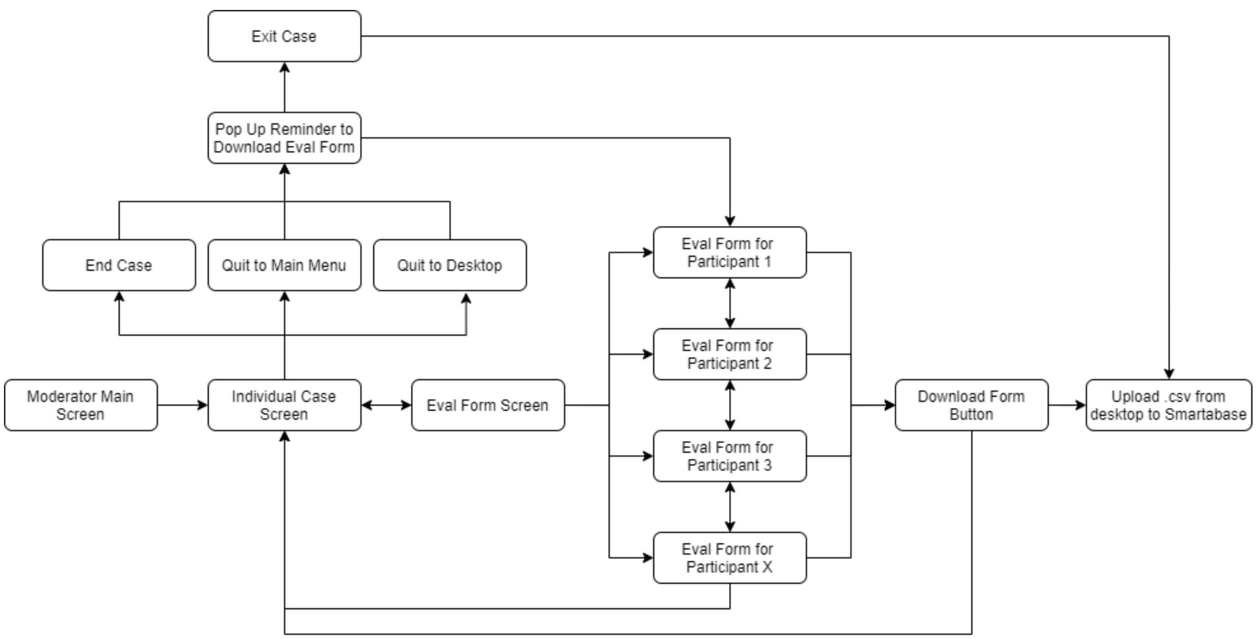

Figure 1: User flow of performance tracking functionality. The map of potential interactions for the moderator to interact with the evaluation and assessment capabilities within the platform.

RESULTS AND DISCUSSION

The VALOR platform was adapted to provide real-time assessment and readiness tracking for each scenario completed by the learner. Within the interface, the moderator has the option of filling out the evaluation form for each participant. Following specification, tracking capabilities were integrated into the proof-of-concept scenarios for testing. A detailed user flow is illustrated in Figure 1. The moderator (person controlling the flow of each case from a computer/laptop) was given additional functionality. They begin with a list of available cases to choose from. After selecting a case, the option to select the "Eval Form Screen" was added, allowing direct evaluation of a case if, for instance, the case was already completed, and an evaluation form was inadvertently not generated prior to completion. After a case was deemed complete by the moderator clicking "End Case," "Quit to Main Menu," or "Quit to Desktop," a pop-up was added to remind the moderator to download and complete the evaluation form. At that point, the moderator would have the option to complete evaluation forms for each participant. Each completed form could then be downloaded, after which the moderator was given the option to upload the form directly to the system.

SimX developed the capability to export performance information collected via the integrated scoring instrument into the pre-existing performance tracking system. This capability included support of the preexisting implementation and relied on the existing APIs and platform capabilities of the database. To facilitate integration, the technical point of contact within the AFRL provided an introduction to the database team and any necessary authorizations and approvals required to develop this integration. Furthermore, appropriate documentation and demonstrations were provided to allow the SimX clinical team to understand how the system would be used by USAF personnel to track performance in SimX scenarios.

In addition to automated tracking, a recording feature was built into the moderator interface to enable playback during simulation debrief sessions. This screen recording feature is accessible within the moderator interface and allows for individual cases to be recorded both in video and audio of all actions within the scenario, including those performed by patients, other characters, and the learners themselves. This feature provides support for: real-time positions of all VR avatars; all interactions with tools, equipment, and characters, and; all moderator actions, including learning objective completions. The system includes integration into a playback system via moderator client, pause, rewind, and replay functionality, and long-term storage of recordings for future review. The moderator can select when to start and stop recording during a case. Files will be downloaded to the moderator's computer and are designed to work specifically on devices with minimal graphics processing capabilities.

CONCLUSION

By implementing a novel and cost-effective training platform within the currently existing standardized tracking model utilized by the US Air Force, we demonstrate the feasibility of sustained and high-quality education that is both measurable and effective. The functionality was successfully implemented into the existing SimX framework, which allowed direct recording and addition to military records of required trainings in a standardized manner. Initial acceptance testing demonstrated the practical usability of the assessment scoring system by training facilitators, and a successful upload capability to the system. Based on this result, further testing and evaluation is planned for an expanded set of trainees. Implementing usability and tracking features – such as automated recording and playback, after-action reports, and integration with the readiness tracking system – will enhance the training experience and provide objective performance assessment of USAF learners. This function ensures that each warfighter receives the training necessary to achieve maximum effectiveness in the techniques, tactics, and procedures applicable to the cases at hand. This adaptation has significant commercial potential for dual use, especially for medical, nursing, and allied health schools.

This ongoing work has illustrated that VR-MST can address the need for standardized and trackable military trainings. With the feasibility established, additional prospective evaluations of a wider subset of learners are the next step. Future adaptations include the development of curricula supporting aeromedical evacuation, advanced resuscitative care, prehospital transport/ Emergency Medical Technicians - Paramedic (EMT-P) certification, and Chemical, Biological, Radiological, Nuclear, and Explosive Simulation Training. These curricula will expand the scope of TCCC training capabilities and additional knowledge, skills, and abilities required for medical readiness while adding to the data that the military can use in tracking operational readiness.

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