The Effect of Difficulty Levels within a Virtual Medical Simulation

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ABSTRACT

Virtual environments provide medical professionals a risk-free setting to practice their skills. Within these environments, medical professionals receive training to reinforce triage, communication, and treatment protocols. Recently, researchers created a medical virtual environment geared towards Combat Medics, focusing on step-by-step training for individual medical procedures. The software requires trainees to manage their aid bag and utilize the appropriate equipment for each procedure. To introduce a 'crawl-walk-run' training modality, researchers implemented a difficulty system into the simulation. In the novice level, simulated patients present readily apparent symptoms with no complications. In the intermediate level, simulated patients have multiple injuries with complications occurring throughout the scenario. The advanced level includes multiple casualties, requiring triage skills, in addition to the skills required at the intermediate level. By altering the difficulty level, researchers studied the impact on trainees in terms of cognitive load and performance. Researchers then conducted a usability study to further evaluate the performance of the system. The results of these studies are reported, including conclusions and discussion regarding successful implementation of difficulty systems within virtual training applications.

ABOUT THE AUTHORS

Matthew Hackett is a science and technology manager for the Medical Simulation Research Branch of the Army Research Laboratory, Human Research and Engineering Directorate, Simulation and Training Technology Center. He manages a variety of projects including the medical holography research and virtual patient research efforts. As a science and technology manager, he oversees these research efforts and conducts test and evaluation to determine their efficacy in the simulation and training domain. Prior to his work with ARL, Mr. Hackett trained to be a government engineer while working as an engineering intern at the Program Executive Office for Simulation, Training and Instrumentation and worked within PM Training Devices. Mr. Hackett received his Bachelor of Science in Computer Engineering from the University of Central Florida and his Masters of Science in Biomedical Engineering from the University of Florida. During his time at the University of Florida, he was a research assistant in the computational neuroscience laboratory, studying the functionality of neurons and how the brain creates neuronal networks. Mr. Hackett subsequently received his Masters of Science in Modeling and Simulation and is currently pursuing his Ph.D. in Modeling and Simulation at the University of Central Florida.

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Steve McIlwain is a Producer for the Virtual Heroes division of Applied Research Associates, Inc. He has over 10 years of production experience in the 3D animation and interactive entertainment industries. Prior to joining Virtual Heroes, Steve worked at Walt Disney Feature Animation and Blizzard Entertainment. Steve specializes in production management, macro/micro scheduling, team building, and finance. He is passionate about creating virtual worlds that educate, inform, and inspire. Steve holds a B.S. in Marketing and an M.B.A. from Azusa Pacific University. At Virtual Heroes Steve is responsible for all aspects of his projects including budget, schedule, development, deliveries, and client relations. He works collaboratively with clients to ensure that the project vision and needs are achieved. Steve guides the internal Virtual Heroes development team to ensure that the team's priorities, communication, and deliverables are unified and focused on successful project completion.

Bradley Willson is the Game Design Lead for the Virtual Heroes division of Applied Research Associates, Inc. He serves as the point of contact on serious-games-related design elements. A nine-year veteran of the game industry, Brad began his career at Rockstar San Diego as a Development Support Supervisor, where he worked on various commercial game titles including the Midnight Club series, Table Tennis, and Red Dead Revolver. He joined Virtual Heroes in 2006, with the goal of incorporating his commercial game experience into games that had a true altruistic focus. At Virtual Heroes, Brad works to create, drive, and deliver the overall creative vision for the numerous serious games in development. Brad creates compelling software designs from conflicting viewpoints, communicates the designs to the development team, and translates the designs into detailed software mechanics, gameplay progression, and interface flow. He constantly strives to provide consistent creative, artistic, and audio direction for all aspects of Virtual Heroes' products. Brad holds a B.S. in Wildlife Science from Purdue University.

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INTRODUCTION

Serious games and virtual simulations have been a growing sector of training for many years. As technology has become more pervasive within our society, training has evolved to utilize the increased capability. Many years ago, training was primarily done in a mentor-protégé modality. Single or multiple instructors conveyed information directly to students with limited technology to assist them. However, currently we have a plethora of technological tools at the disposal of instructors, ranging from Powerpoint presentations to virtual or live simulations. Virtual simulation-based training in particular has advanced rapidly, in large part due to increases computational power. The increase in virtual simulations can be seen across the spectrum of training domains: flight simulations, train simulations, tank simulations, and even equipment to train the operation of farm equipment. All of these virtual simulations allow a trainee to practice skills in a risk-free virtual environment for minimal cost.

One area showing significant growth has been in virtual medical simulations. Virtual medical simulation can train medical professions ranging from first responders to surgeons. A plethora of serious games have been developed in order to supplement existing training medical programs. For example, virtual medical simulations have been developed for training diabetes care in an adventure game format (Diehl et al., 2011). On the other end of the spectrum, a serious game was developed as an surgical and team training aid, with a focus on the operating room(Gallagher et al., 2005). The variety and number of virtual medical simulations is increasing rapidly as more and more uses cases are developed. A recent study focusing on surgical simulation found over 30 validated medical simulations in published articles, divided into two categories: developed for specific educational purposes (17) and commercial games also useful for developing skills relevant to medical personnel (13) (Graafland et al., 2012), and this is only a small segment of the field.

The growing number of virtual medical simulation demonstrates the changing paradigm in medical education and training, and there is substantial rationale behind such a shift. To begin, students and instructors are realizing the value inherent in virtual medical simulations. In a recent survey of over 200 medical students, results indicate that the overwhelming majority of medical students believe virtual medical simulations have a great deal of educational value. In fact, over 97% indicated they would use virtual medical simulations if they were fun and helped to improve skills associated with patient care (Kron et al., 2010). These attitudes are driven by a number of studies which have shown the efficacy of such training. A virtual simulation geared towards Combat Medics was shown to be effective in improving learning outcomes (Sotomayor, 2010). At a higher echelon of care, researchers found that improvements due a virtual medical training improved operating room performance (Seymour at al., 2002).

Within the military specifically, virtual training has been emphasized. The Army Training and Doctrine Command (TRADOC) released a document outlining the Army's vision of training in the future, called the Army Learning Concept 2015 (ALC 2015, 2011). TRADOC emphasized the need for more distance learning capabilities, in order to provide "anytime / anywhere" training. To target this need, the Army Research Laboratory has worked with Applied Research Associates, Inc. to develop a next-generation training simulation focused on the Combat Medic curriculum. The application, called Virtual Combat Medic, will take advantage of recent research in medical simulation, including high fidelity physiology modeling, realistic graphics, multi-player capability, and a difficulty system. The difficulty system in particular is a significant accomplishment, allowing instructors to tailor training to the capabilities of the students. Within this paper, researchers will discuss the research and development process used to create Virtual Combat Medic. Additionally, the paper will report results from a user test conducted at Fort Bliss which assessed the usability and utility of the application. The conclusion will discuss the strengths and weaknesses found during the user evaluation, and the future work planned.

RESEARCH BACKGROUND

Gameplay Design

The first phase of research was focused upon gathering the appropriate training objectives. A thorough task analysis was conducted through discussions with subject matters experts. Additionally, training manuals such as the 68W manual and the Army's medical tables for training assessment were used to ensure that the serious game would meet training needs (TC 8-800, 2009). With the foundation based on the training goals, researchers chose to focus on the top 3 preventable deaths of the battlefield: hemorrhage, tension pneumothorax, and compromised airway. A scenario was created to train the treatments of these injuries. The gameplay was designed to be as realistic as possible, requiring participants to manage their aid bag, utilize the appropriate equipment, and perform each small step in a procedure (Figure 1). For example, in order to apply a tourniquet, the user has to 1) take the tourniquet from the aid bag, 2) select the appropriate location, 3) tighten the windlass, 4) secure the windlass, and 5) check to ensure the tourniquet is secure and the distal pulse has subsided. The focus on procedural steps within medical interventions was designed to reinforce medical skills in a more comprehensive way than current simulations. The development team also chose to remove the ability to move around the world freely, instead focusing on docking points for treatment. The free movement in the virtual world did not meet any training requirements regarding the procedural treatment steps, and the docking points allow users to move to any point on the body where treatment occurs. After participants perform all necessary medical interventions, a medical evacuation is called in, and the participants move into an after action review phase. During this phase, participants are given a GO / NO-GO checklist detailing what they did right and wrong. Additionally, all of the physiology measures are shown to the participants so they can see how the patient responded to each of their actions.

Figure 1: Gameplay Screenshots showing Junctional Hemorrhage and Tourniquet Application

Physiology Modeling

The HumanSim physiology engine is a high-fidelity physiologic-pharmacologic model and dynamic virtual human technology. The engine responds dynamically to simulated trauma and treatment in real-time for each scenario: hemorrhage, tension pneumothorax, and compromised airway. Real-to-life heart rate, blood pressure, O2, and intravascular volume are accurately modeled for the user to review within each treatment scenario. This provides unprecedented immersion and accuracy in the application**.** Additionally, the physiology model can combine multiple wounds using the difficulty system (see below). For example, a patient can have both a hemorrhage and tension pneumothorax wound and the physiology engine will respond accurately. The vitals are displayed in the debrief stage for both individual assessment and instructor based feedback. In order to ensure that the physiology models were correct, the research team enlisted subject matter experts at the Duke School of Medicine to validate the system. After extensive testing and evaluation, the system was determined to accurately model all the physiology metrics associated with the treatment of these injury variants.

Difficulty System

The difficulty system attempted to recreate the crawl-walk-run technique used in training. The normal or 'crawl' difficulty presents users with standard wounds with no complications. A scenario might include a single hemorrhage wound or a simple tension pneumothorax (Figure 2). The advanced or 'walk' difficulty level presents users with a casualty with multiple wounds and complications. These complications include: misleading cues, such as excess blood, misleading uniform tears, a delayed medevac, and many more (Figure 3). The wounds presented in the advanced scenarios are randomized, adding greater replayability during training. Lastly, the expert or ‘run’ difficulty includes multiple advanced difficulty casualties with multiple wounds. This requires participants to not only treat casualties, but also triage the situation and treat the most life-threatening wounds first (Figure 4).

Figure 2. Normal Difficulty Setting.

Figure 3. Advanced Difficulty Setting. Single Casualty with Multiple Wounds

Figure 4. Expert Difficulty Setting: Multiple Casualties Multiple Wounds

User Interface

The user interface was designed to be minimal, allowing trainees to focus on the casualty rather than the on the controls. The control scheme focuses entirely on the mouse, making it easier for users who are uncomfortable using the WASD keyboard control scheme common in many virtual simulations. The user looks around the environment using the right mouse button, and selects equipment and treatment options with the left button. To begin treatment, the user hovers over a body part, which then becomes highlighted (Figure 5). By left clicking, a menu with the possible treatment options for the selected body part appears (Figure 6). If a menu selection is grayed out, an explanation is shown by hovering over the selection; for example, the option to apply a tourniquet to the leg will be grayed out if the tourniquet is not equipped. Interaction with their aid bag is done in a similar fashion. The aid bag opens by hovering over and left clicking; then users can select the necessary equipment and either equip it immediately or place it on the ground for easy access at a later point (Figure 7). Movement in the environment is isolated to essential movement needed for treatment. Movement from docking point to docking point is done by simply left clicking on a docking point.

Figure 5. Casualty Highlight User Interface.

Figure 6. Treatment Options User Interface.

Figure 7. Aid Bag User Interface.

EXPERIMENTAL DESIGN

The test event included 17 Combat Medics who assessed the virtual medical simulation. The average experience level of the Medics was 2.5 years. All medics were in the same room with a local area network configured to run the application (Figures 8,9).

Figure 8. User Evaluation Image #1.

Figure 9: User Evaluation Image #2

The experiment began by giving the Combat Medics a short background brief on the aims of the study. The researchers instructed participants on how to begin a scenario. The participants were given minimal instructions on the controls of the game in order to assess the ease of learning the control scheme. The participants completed all three of the scenarios on the normal difficulty setting first. Participants then completed a survey to indicate their mental effort needed to complete these scenarios. The mental effort survey was a variant of the NASA TLX, focusing on mental effort and excluding the other dimensions. Participants rated their mental effort from a 1 (very low mental effort) to a 7 (very high mental effort). After a short break, participants completed all three of the scenarios on the advanced difficulty level. Participants were given a survey assessing their mental effort during the advanced difficulty level. Finally, the participants were split into teams of three to four to complete the expert scenarios involving multiple casualties. The teams were able to communicate by speaking directly to one another, as they were seated at the same table. After completing the expert difficulty scenarios, participants completed the final mental effort survey. At the conclusion of the event, participants were given a final survey to assess their opinions regarding the usability and utility of the application. The survey included a number of questions with Likert scales to quantitatively evaluate the opinions of the medics. Additionally, a number of open-ended responses were used to gain any feedback that wasn't specifically asked in the surveys. Once the surveys were completed, the researchers engaged in a guided verbal discussion to allow for the group to detail their perceived strengths and weaknesses of the training application in a group setting.

RESULTS

The experiment had a number of significant findings regarding the Virtual Combat Medic application. The difficulty system was very successful at escalating the challenge of the scenario. In the normal setting, the participants reported an average mental effort of 4.9 ± 0.46. In the advanced difficulty level, the participants reported an average mental effort of 5.9 ± 0.35. The difference in experienced mental effort between the normal and advanced difficulty level was significant ($p<.05$), indicating that the increase in difficulty was definitely experienced by participants. For the expert difficulty level, participants reported a mental effort of 6 ± 0.37. The expert level produced significantly greater mental effort than normal ($p<.05$), but only a marginal amount more than advanced ($p>.05$). The results are shown in Figure 10.

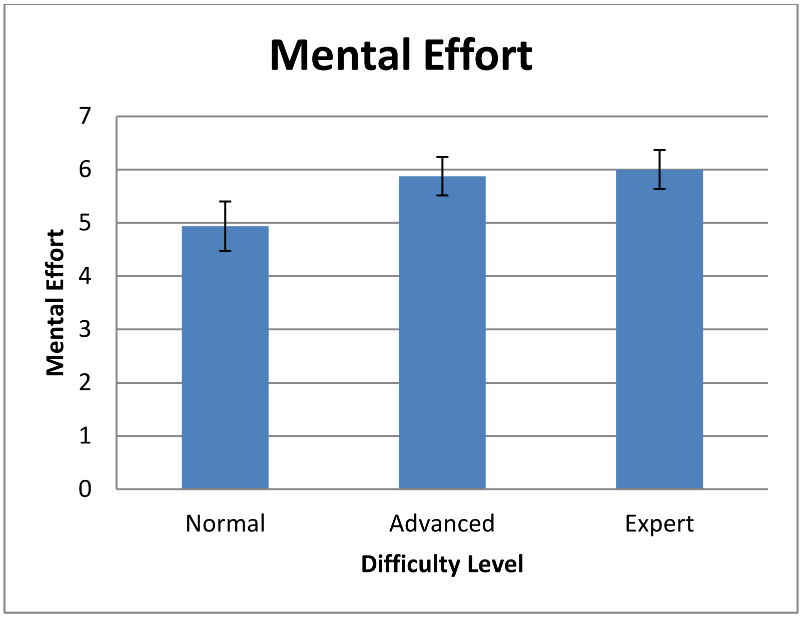

Figure 10: Mental Effort Experienced by Participants Across Difficulty Levels

A number of questions were designed to gauge user satisfaction using a Likert scale from 1-10. The average satisfaction for the user interface portion was a 8.1±0.79, indicating that the users felt the interface was intuitive and easy to navigate. The satisfaction of the game as a whole was a 7.6±0.54. indicating the test population had a very positive outlook on the training application. The user satisfaction metrics are shown in Figure 11.

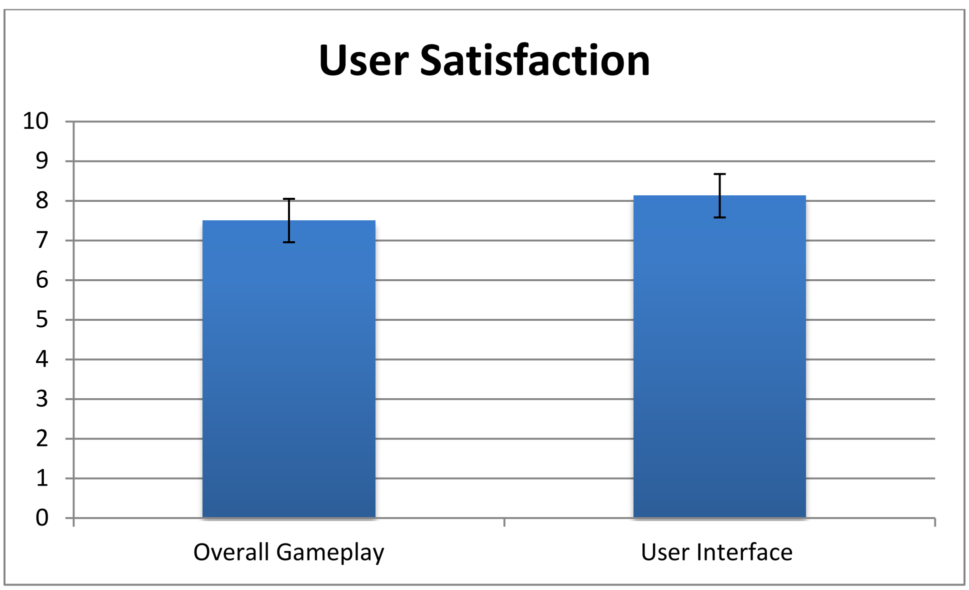

Figure 11: User Satisfaction on a scale from 1-10 for Gameplay and User Interface

The open ended questions were coded into positives and negatives, to formally analyze the responses. The vast majority, 16 out of 17, believed the simulation would be a useful and beneficial tool for training. The recovery from errors was quick and easy, according to 15 of 17. Feedback in the game was given during the scenario by way of occasional text based prompts, graphical cues, and a detailed after action review; all but 2 of the participants felt the feedback was sufficient. As previously mentioned, the user interface was rated highly according to the Likert scale questions, and the open ended questions reinforced that finding. To begin, 14 of the 17 participants indicated the control scheme was easy to learn. Additionally, 15 of the 17 felt the user interface was simple. The parallels between the open-ended questions and the quantitative questions emphasize the fact that the Virtual Combat Medic application met user training expectations and ease of use. The open-ended questions are summarized in Figure 12.

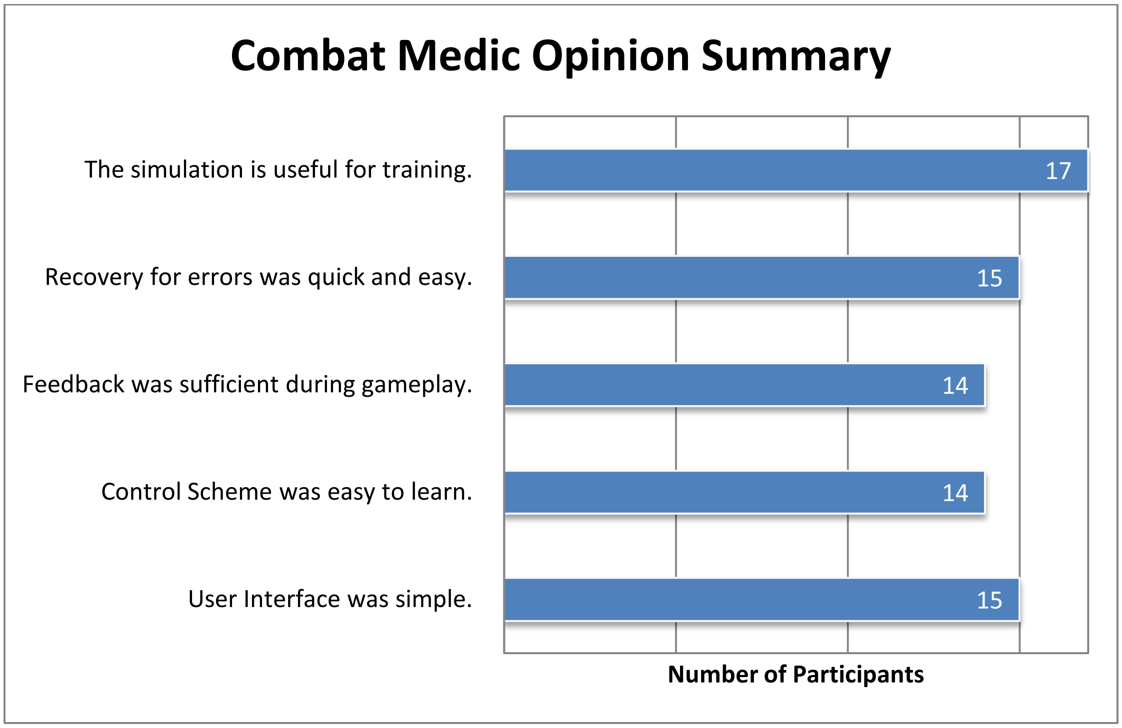

Figure 12: Number of Participants Responding Positively in the Open-Ended Questionnaire

CONCLUSION

The Virtual Combat Medic prototype has shown significant promise thus far. To begin, the instructional design team focused upon training objectives when implementing a software and user interface design. The user interface was intentionally minimized, allowing the user to focus on the casualty rather than the controls. To complement the gameplay, the project developed a unique high-fidelity physiology engine with cardiovascular and respiratory models. These models would allow for the casualties within each scenario to respond appropriately to the performed medical interventions. Lastly, the difficulty system included normal, advanced, and expert, to allow for crawl-walk-run training.

The Virtual Combat Medic application user test was very successful and revealed a number of important findings. First, the difficulty system was effective in modulating the challenge of the scenario. Users showed significant differences in mental effort between the normal and advanced as well as the normal and the expert. The advanced and expert were similar in difficulty, despite the expert having multiple casualties. Researchers expected a larger difference between these two. A probable explanation for the small difference between advanced and expert may be attributed to the inclusion of multiple trainees in each scenario. By having one or two additional medics treating casualties and working as a team, the users did not have to worry about triaging and moving from patient to patient. The only additional cognitive load came from communication between the participants. In future testing, the mental effort needed to complete the expert difficulty scenarios will be assessed with each participant individually as well as in a team.

The usability and utility metrics indicated a very positive outlook on the Virtual Combat Medic application. The users were positive about both the overall gameplay and the user interface. Furthermore, the open-ended questions showed nearly all participants felt the application was useful for training and easy to use. An excellent way to predict the adoption of a technology is to use the technology acceptance model (TAM). This model focuses on perceived ease of use and perceived usefulness (Davis, 1989). The metrics collected during this study closely mimic the TAM; based on the highly positive outlook from participants; therefore, researchers predict that the technology would be accepted by the user group.

While the user group was very positive towards the application, they consisted of many young medics who were gamers. Out of the 17 total, 13 self-reported as gamers, with 7 playing games more than 1 hour per day. The fact that the participants were already interested in gaming may have made them more interested in the Virtual Combat Medic application. While this may be indicative of the newest generation of Soldiers coming into the Army who are more comfortable playing video games, researchers intend to do larger studies to gauge ease of use and usefulness in the opinion of both gamers and non-gamers.

The primary weakness found by the participants was a lack of a tutorial. Though the control scheme was rated as easy to learn by most, many expressed a short initial frustration period. Simple tasks such as looking around by holding the right mouse button were not intuitive to many participants. The majority felt a simple video or walkthrough tutorial would eliminate this frustration entirely.

In summary, the Virtual Combat Medic application research and development process produced many features new to virtual medical simulations. The application was tested and received positive feedback by a group of Combat Medics. The difficulty system was highly successful, and will allow instructors to tailor scenario difficulty to the current skill of students. Future work in this application will be to create a tutorial portion of the application to ensure users understand the control scheme immediately. Researchers also plan to continue to refine the scenarios and build upon the feedback given by the participants during the user evaluation.

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