VR TRAINING SOFTWARE

Research Shows Strong Results for Learners

By John Rolando, Kausalai (Kay) Wijekumar and Rhett Barnes

MANY HIGH-IMPACT CAREER FIELDS such as law enforcement and first responders to threats now require strong, high-quality training in complex science topics such as radiation, chemicals, and explosives detection and mitigation. In addition, more students must be encouraged to enter science, technology, engineering and math (STEM) disciplines to sustain innovation and encourage transformations for the future of our society. Unfortunately, many traditional learning environments have lost their luster in achieving transformational change in increasing STEM motivation and learning, as evidenced by the dwindling STEM pipeline in schools. A recent article shows that interest among teen boys in STEM careers after middle school has dropped precipitously from 36% to 24% in the past few years (Marotti, 2018).

The traditional approaches to learning such as instructor-led hands-on training is costly and cannot be delivered quickly to geographically dispersed locations. Lecture-based instruction, printed materials and multimedia videos do not support strong, on-demand, consistent and high-quality training for first responders to threats. These personnel may be situated in remote locations or may not have the ability to travel for in-person training. First responders also have diverse background knowledge and are not expected to be experts in science. Experiencing the use of detection equipment through virtual reality (VR) may provide the closest thing to hands-on training in time-sensitive and geographically dispersed situations.

KEY TAKEAWAYS
- **Realistic Adaptive Interactive Learning System (RAILS) is a game-based virtual reality learning software developed for training first responders.**
- **The software helps users learn how to detect and mitigate explosives in a scenario-based system with help from a virtual tutor.**
- **Research conducted with a diverse group of graduate students shows that RAILS users outperformed the control group on posttest.**

This development and research focused on training first responders using the Realistic, Adaptive, Interactive Learning System (RAILS) and comparing their learning outcomes to those of participants who read and studied the same information in printed format. The research utilized the RAILS-X (learning system for explosive trace detection) beta software package. This article presents the theoretical foundations of the VR learning system, design elements of the system, research design, results and conclusions.

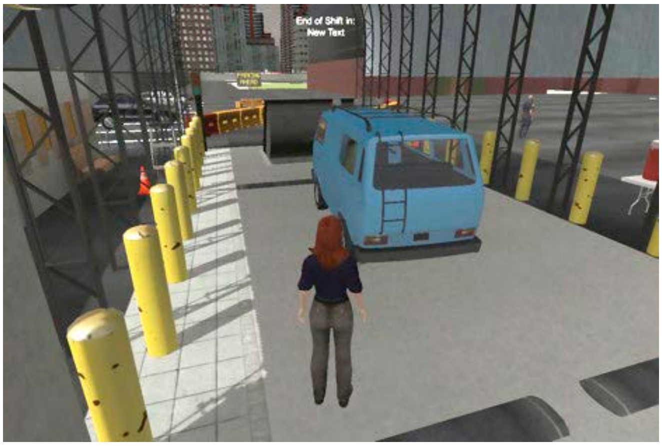
Background

In an increasingly complex and violent world, first responders and military personnel require training in vast numbers of threats, detection and mitigation in a timely manner. Based on the needs of trainees, these trainings must also be easily available and portable to take to remote geographical regions. Training for explosives detection in a traditional format may be cost prohibitive and cause additional threats because of the need for transferring actual chemicals to sites, transporting detection equipment and providing actual realistic settings for such training. Because of the high costs and logistical challenges, these trainings cannot take place often and cannot be set up on an as-needed basis.

Given the nature and diversity of the threats, training quality is of utmost importance and can mean the difference between life and death. Adding to the complexity of developing quality training is the heterogeneity of backgrounds of first responders and law enforcement personnel being trained, and the geographically dispersed locations of their work. These personnel have diverse academic backgrounds (e.g., non-science college degrees) but are charged with using complex pieces of detection equipment and conducting assessments in volatile and highly stressful situations to detect and mitigate threats.

These first responders require high-quality training that will allow them to easily learn and transfer knowledge to realistic settings. Another factor related to training for first responders is the need for expensive resources that may also present unrealistic risks (e.g., setting up scenarios with real chemicals). Both first responders and students could benefit from high-quality training that will help them learn complex content and be able to solve problems easily.

The volume and sophistication of computer-based training systems has consistently improved in recent years, but research outcomes remain modest (Barrow, Markman & Rouse, 2009; Kim, Samson, Fitzgerald, et al., 2010; Meisch, Hamilton, Chen, et al., 2011; Pane, McCaffrey, Slaughter, et al., 2010; Pane, Griffin, McCaffrey, et al., 2014; Wang & Woodworth, 2011; Wijekumar, Hitchcock, Turner, et al., 2009; Wijekumar, Meyer & Lei, 2012). Reasons for these mixed results may be related to the types of learning and lack of motivational relevance to the learners.



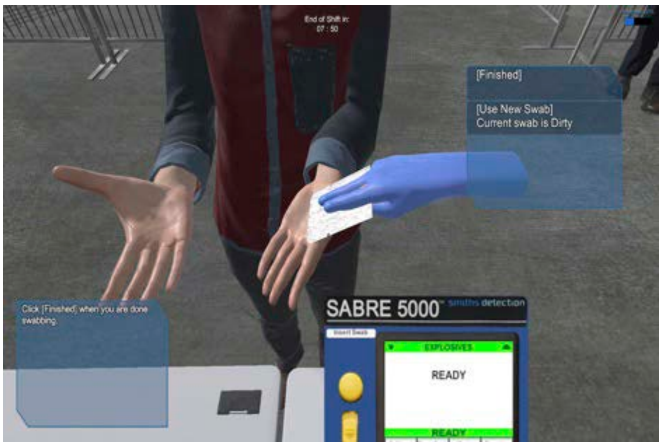


Figure 1 (top): RAILS-X scenario of first responder checking on vehicle at checkpoint.
Figure 2 (bottom): Example image from the RAILS training showing a student swabbing the hand of a person to test for explosive trace particles.

This project taps into utilizing scenario-based learning systems supported by game engines (Mikropolous, 2006). The sophistication of these types of systems present a unique solution that may be extended to other STEM learning disciplines (Merchant, Goetz, Cifuentes, et al., 2011) to encourage more students to be interested in entering science-related careers. Many different approaches have been tried and tested in computer-based learning systems related to multimedia learning (Mayer, 2011) and these results are promising but not impactful for training first responders. An underexplored area within these computer-based learning environments remains the sociocultural and expectancy-value contributions to the design of the environments and learning outcomes. Combining sociocultural approaches and expectancy-value theories allows designers to develop powerful learning environments that bring all the motivation and real factors of complex situations in a cost-effective and safe manner. This project is such an advancement utilizing a scenario-based multimedia game engine to provide first responders with powerful realistic training on threat detection and mitigation.

Theoretical Basis

The theoretical framework for the learning system uses the sociocultural approach to learning and the expectancy-value theory. The sociocultural segment draws on Vygotsky's (1978) theory of social constructivism to support learning. According to his definition, human development is socially situated, and knowledge is constructed through interaction with others. Further, realistic learning systems include all the artifacts that are necessary for the completion of the learning task. Thus, the system utilizes role-playing game scenarios with multiple first-responder avatars and trainer/expert scaffolding for learners. The system is set up for learners to use the correct equipment, scenarios and necessary regulations for safety, security and chain-of-command procedures. The lessons present the complex nature of the detection and mitigation context, making it a powerful sociocultural learning system.

Another important theory for the design of the system is the expectancy-value theory (Eccles, 1987), which explains how the expectancy of success and task value determines motivation. According to Eccles and Wigfield (2002), student motivation is directly linked to expectations of success or failure at the task. In both explanations of this model, student choices are shaped by negative or positive attributes of the task at hand (Dietrich, Viljaranta, Moeller, et al., 2017). Therefore, students are motivated to complete the task depending on its value to them. Eccles (2009) predicts that students are likely to select activities where they have a high expectancy of success. Thus, the RAILS-X development focuses on real-life scenarios presented in VR learning systems. Further, the learning environment contains all the artifacts and collaborators to assist the learner. The system provides scenarios that are motivating to learners and increases their expectancy for success. These factors mean that students will sustain their interest and practice for longer times and learn more from their experiences. This is a powerful and important consideration for first responders and law enforcement officers who may have varying backgrounds and be unsure of their ability to cope with the demands of complex scientific concepts surrounding the explosives detection and mitigation learning modules.

System Design

Within the RAILS system, learners are placed in problem-solving roles; they learn how to safely use equipment that is used in threat detection and further learn how to mitigate the situation. The scenarios contain information about the use of safety and protective equipment, regulations, considerations for alternative approaches and correct use of detection of equipment. Within each scenario, learners have the opportunity to watch videos and act the role of the first responder avatar. They are given guidance about the scenario and scaffolded by a virtual instructor based on their responses to the activities in the virtual learning scenario. They also receive feedback on their use of the equipment and correctness of their detection activities. Figure 1 shows a sample screen where the first responder is making important decisions about the location of a threat, an example of one problem-solving role the student encounters during training.

Learners have access to many different types of learning modules, including modules about specific devices, safety equipment use, detection of threats and how to mitigate them. Learners can move around the virtual environments similar to a video game, and an instructional tutorial is available to learners who do not have video game experience. Figure 2 shows how a learner can use the VR system to practice swabbing the hands of a person and detecting the threat. Figure 3 presents a scenario similar to an airport cargo storage or warehouse that needs to be checked for threats.

The system uses a Moodle course management platform for students to register and login to the software. The software is linked to the site and can be downloaded to laptops or be used via the Internet (Figure 4). Each user is issued a username and password to access the system and keep track of their activities and performance. The costs are minimal but vary based on the number of personnel enrolling from an organization. There is a user training included with the software for users to learn how to control the VR trainee, devices and move around the screen. Within the lessons there is a virtual instructor and help available to assist the learner. Training reports and logs are available to local leaders to track student progress through the system.

Research Design

A randomized controlled study was conducted with 45 graduate students enrolled in a large university in the southern U.S. Participants were recruited through a listserv announcement and were randomly assigned to use the VR software or participate in the control group where they were given the same instructional information in paper format.

Research questions guiding this study were:

1) What are the effects of the learning system compared to the control group on a content knowledge test?

2) What are the motivation outcomes of using the learning system?

Participants

The participants had an average age of 25 and were enrolled in either master's or doctoral degree programs in the sciences. Approximately 40% of participants were enrolled in engineering programs and 25% were enrolled in computer sciences. Others were enrolled in chemistry or physics programs. Of the participants, 44% were white, 33% were Asian and 23% were Hispanic or black.

Procedures

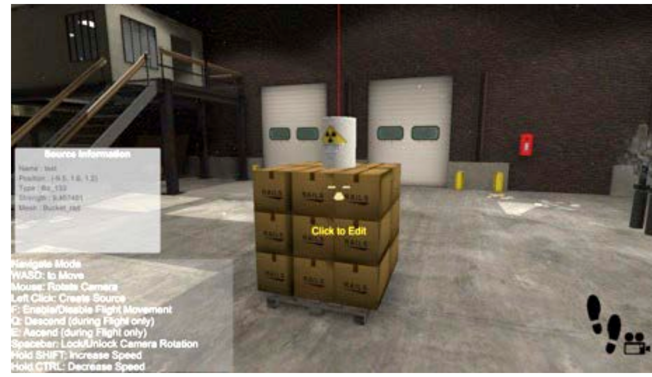
Students responding to the listserv announcement were provided with eight different 2-hour time slots for participation in the project. Initially, 52 students submitted an e-mail expressing interest but only 45 were able to register for the time slots. All participants received a gift card and were also entered to win a tablet device. Two separate sessions were conducted due to weather-related challenges during the initial data collection efforts. After sign-ups were completed, participants were randomly assigned to use the learning system software or participate in the control group.

All participants were administered an informed consent form prior to their participation. After signing the consent, all participants completed a pretest on the learning content. Participants also completed a demographics questionnaire. Next, participants who were assigned to the RAILS-X group logged into the system using a username and password, and completed approximately 70 minutes of interactions on two learning modules. After completing the VR training modules, the participants completed a posttest. The participants assigned to the control group read the same content in printed format. After reading the material, they completed the posttest. At the conclusion of the data collection, all participants were interviewed by the researchers about their efficacy toward the learning systems.

The researchers chose to have the control group use written practice materials (similar to user manuals provided with most detection devices) because that is the typical procedure for most law enforcement and first responder training. Most organizations do not have the resources to train all personnel regularly on all types of devices that may be used in responding to a threat. Personnel also have a variety of backgrounds and are not necessarily trained in chemical, radiological, biological and explosive material detection and mitigation. In typical law enforcement or first responder organizations, there may be a few well-trained personnel who serve as leader, but the rest of the group will need on-demand training in time-sensitive situations. Teacher-led training with hands-on experiences are costly and cannot be scheduled in quick-turnaround situations. Thus, many organizations opt to use manuals as the primary resource for training. Therefore, the researchers' choice of activity for the control group was realistic and valid for a comparison.

Measures

Two equivalent content knowledge tests were administered at pre- and posttest. Both forms had 15 items focused on content knowledge recall, inference and application questions. Both forms were highly reliable with a split-half reliability of .92. The questions were multiple-choice format.



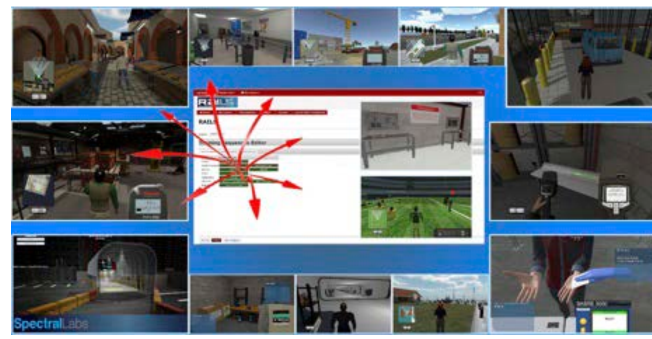


Figure 3 (top): A scenario within RAILS-X showing a warehouse or airport cargo storage location that needs to be checked.
Figure 4 (bottom): Moodle platform showing links to the many VR training systems for learners.

An additional measure of demographic questions was also administered to participants. Finally, all participants were interviewed on their efficacy for the learning systems. The students were asked how easy and motivational the learning systems were (VR or paper).

Results

The most appropriate method for data analysis of this sample was a 2-tailed t-test to compare the means of the pretest results to ensure baseline equivalence between the VR group and control group. To answer the first research question about the learning outcomes, the researchers conducted a 2-tailed t-test to compare the means of the posttest results between the two groups. The purpose of analyzing the pretest scores is to ensure that the two groups did not differ significantly at the beginning. The purpose of analyzing the posttest results was to determine whether there was a significant difference in understanding, recall and application of knowledge regarding the learning modules in people who read a set of instructions (control) and people who used the VR software (experimental) to further their understanding of the detection and mitigation of threats modules.

Table 1 (p. 38) provides data output of the 2-tailed t-test of the pre- and posttest. The pretest means of the control group (5.38) and experimental group (5.62) do not differ significantly ($p = .5886$). Thus, the experimental and control groups were equivalent in their knowledge at pretest. The posttest means of the control group (9.00) and experimental group (12.33) were determined to have a significant difference ($p < .0001$). This shows that participants given access to the VR software had a better understanding and ability to recall and apply knowledge regarding the learning system than participants who were given only a set of instructions. The results show strong effects and are statistically significant.

A compilation of the interview questions showed that participants using the learning system software were pleased with the

TABLE 1
VR & CONTROL GROUP MEANS AT PRE- & POSTTEST

Group	Pretest mean (SD)	Posttest mean (SD)
RAILS	5.62 (1.53)	12.33 (1.8)
Control	5.38 (1.47)	9.0 (1.5)

interface, interactions and usability of the system. They noted that the software provided a strong motivational system by displaying the real-life scenarios in the VR environments. They also noted the highly engaging nature of the content and that the software made them feel useful in solving highly complex situations. Most respondents also noted that they enjoyed the game-like features and acknowledged the cost-effectiveness of using the software. Respondents who read the paper version of the lessons reported difficulty in understanding the content and learning how to apply the knowledge.

Overall, the learning system randomized controlled trial resulted in strong and positive results favoring students who used the software. Both learning and motivation were positively affected by the software system, indicating that RAILS-X is an effective learning tool in addition to providing a cost-effective and safer learning environment for geographically dispersed learners with diverse backgrounds.

Discussion & Value for OSH Professionals

Based on the theoretical foundations and thoughtful design of the learning system, the research findings present promising evidence to suggest that VR training systems may be useful to the broader occupational safety community. Almost all large organizations have a need for OSH personnel and some security personnel who will be the first to respond to any potentially dangerous situation within their offices or workspaces. Additionally, many factories, power plants, hazardous waste disposal locations, manufacturing organizations and hospitals require personnel who could cost-effectively receive high-quality training through VR systems such as RAILS-X. The VR approach can make the training readily available to a larger number of employees and even present the training to those who may not typically be trained due to the high costs. Most importantly, as technologies and new detection equipment are routinely updated in organizations, VR trainings may be useful for quick, high-quality training and offer a refresher for those who have not recently attended training and used the devices. Thus, VR provides the following advantages:

- high-quality training;
- on-demand for quick turnaround;
- brush up as needed for personnel;
- custom training for personnel with varied backgrounds and different roles within the organization (e.g., detection team, safety team);
- provide realistic training without travel cost or hazards of using real threats or chemicals;
- provide access to geographically dispersed personnel;
- cost effective.

Each organization should seek out VR training based on its specific needs and select which personnel within the organization will be trained. The VR training can be customized to different personnel with different needs (e.g., detection, mitigation team, OSH team). Applications of the VR approach are already in use with medical personnel where doctors in remote locations receive training on using different devices without having to travel to central training facilities. Similarly, VR solutions may be a cost effective, high-quality and efficient alternative to other forms of training for safety personnel. **PSJ**

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John Rolando is vice president of the Technology Development Division at Spectral Labs Inc.

Kausalai (Kay) Wijekumar, Ph.D., is director of the Center for Urban School Partnerships as well as a professor of teaching, learning and culture in the College of Education and Human Development at Texas A&M University.

Rhett Barnes, Ph.D., is chief technology officer at Spectral Labs Inc.