Simulations to Train Buried Explosives Detection: A Pilot Investigation

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ABSTRACT

The U.S. Army seeks to identify cost-effective methods to deliver training. Augmented Reality (AR) and Virtual Reality (VR) are proposed to offer low-cost, ubiquitous hands-on training for Improvised Explosive Device (IED) detection (i.e., Minehound device) training. Given the objective to assess new technologies, the primary goal of this initial study was to examine users' reaction and performance using AR and VR trainers in a field experiment. Ten Warfighters were randomly assigned to either the traditional training (i.e., control condition) or the experimental training (i.e., first VR, then AR training). Objective data was logged as post-training IED detection accuracy and multiple-choice pre- and post-test scores. Subjective surveys were used to gauge participant reactions to the training. Initial descriptive results indicate marginal mean differences, with less than a five-point difference between the traditional and experimental groups for post-training IED detection accuracy. A minor increase, of less than 10%, from pre- to post-test multiple-choice scores was found in both groups. Results from a workload survey showed a pattern of increased scores across all subscales for the experimental group. Results from the open-ended questions provided evidence to substantiate the objective data. The results underscore a cost-benefit analysis, indicating the value of using AR and VR technologies for IED detection training. The use of AR and VR technologies show potential as a supplemental tool in the training continuum. The next steps for this research initiative will focus on expanding the sample size to accommodate three conditions (i.e., control, VR, and AR conditions). Additionally, the initial results will need verification to confirm the current trends in workload.

ABOUT THE AUTHORS

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Crystal Maraj is a Research Assistant Professor employed by the Institute for Simulation and Training (IST) at the University of Central Florida (UCF). She has attained her Ph.D. in Modeling and Simulation (M&S) from UCF. For the past four years, Dr. Maraj has worked for the Simulation & Training Technology Center (STTC) as a Researcher on medical simulation technology projects as well as developing and implementing empirically based research experiments for Simulation-Based Training (SBT) platforms. Dr. Maraj has published research findings to inform the scientific and training communities to improve trainee performance and training system utility. Most recently, she is leading the Realistic Assessment of Performance in Devices (RAPID) lab that focuses on the evaluations of VR/AR technologies assessing capabilities, deficiencies, specifications, costs, maturity and risks. This information will inform the military community of the technology readiness of devices.

Jonathan Hurter is a research assistant at the University of Central Florida's (UCF's) Institute for Simulation and Training (IST). Holding a Master's degree in Modeling & Simulation from UCF, Jonathan has worked with human-based research topics, including the relation of avatars with performance, the usability of virtual reality systems, and the effects of instructional strategies for signal detection. His efforts fall under instructional design and technical communication, mainly.

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BACKGROUND

A typical counter-Improvised-Explosive-Device (IED) training course requires 40 hours of instruction, including lectures and hands-on training with handheld IED detectors. The traditional training course comprises of lessons, which shows the basic setup, operations, and sweep technique of the Minehound. Following the traditional training, a multiple-choice exam is administered to assess the retention of the information disseminated throughout the 40-hour course. Traditional counter-IED training courses pose several challenges, such as monetary costs, the risk of skill degradation, and the lack of accessibility. Warfighters are responsible for handling the counter-IED equipment, or Minehound detectors: if the equipment breaks, the Warfighter is responsible for the cost to repair or replace the device. As a result, Warfighters are limited, by unit cost, free access to the Minehound handheld detector for practice and sustainment exercises. In terms of other costs, travel from a home station to a special range is limiting, as are creating specialized ranges with soils samples imported from overseas. Even if the Warfighters are trained to use the device, months or years may pass without sustainment training, resulting in the risk of skill degradation. Additionally, Warfighters may be deployed to locations where access to the Minehound device is limited.

The current project goal was to develop a Minehound training device that provided low-cost, ubiquitous hands-on training for IED detection. A cost comparison of commercial-off-the-shelf devices (e.g., Android phones and tablets; and head-mounted devices) was used to maintain a low cost on the device. The developed Minehound trainer device offers a variety of training approaches, ranging from digitized versions of traditional field manuals to immersive synthetic environments with a system walk-through. In one simulation form, a high-fidelity, Augmented-Reality (AR) representation of a real-world training range enables the trainee to imitate the motion of a sensor sweep. In addition, the trainee is asked to calibrate the device by configuring the device in a visually realistic environment that includes soil composition.

The use of simulation in conjunction with the traditional, Real-World (RW) training has several advantages. A simulation replicates and abstracts a real system. At best, simulations approximate a concrete system through high fidelity: they provide a system which looks and functions in the manner of a real task. Virtual Reality (VR) and AR are sought to advance training, with a goal to accelerate learning, deliver training at a ubiquitous point of need, and be affordable (Army Research Laboratory, 2014). In terms of the experimental Minehound device investigated for this study, specific advantages included reduced sustainment costs from 3D-printed parts and consumer electronics; reduced demand for instructors and repair costs of the traditional Minehound device; and to simulate Ground Penetrating Radar (GPR) behavior accurately ("Detection and Sensing of Mines…,")

INTRODUCTION

Given how the use of IEDs may contribute both physical and psychological injury to Warfighters and civilians, IEDs have become detrimental in military warfare. Enemy IED efforts have persisted during recent wars (Kester & Winter, 2017; Zoroya, 2013). According to the United States Secretary General (2016), enemies easily plant IEDs since they are easy to make, are low-cost, and are developed with readily available components. Ultimately, deterring the destructive force of IEDs (here in the form of buried explosives) leads to a need for improvement in training. From 2011 to 2015, more than 6,300 recorded IED explosions were reported, which resulted in over 105,000 casualties (Secretary General, 2016). As enemy IED threats continue to progress, AR and VR training has the potential to improve detection effectiveness in the field.

By blending traditional training (including lectures and hands-on training) with the digital aspects of AR and VR training, another layer of simulation is offered as improvement on the traditional training. Here, a teacher-centric methodology prepares students, where a student can receive additional lifelike practice through a simulation classified as “practiceware” (Aldrich, 2009, p. 438).

Similar Training Technologies

At the time of this writing, new simulations have begun to emerge for practicing handheld detection of buried explosives, including both AR solutions and VR solutions. The Mine & IED Detection Augmented by Satellite (MIDAS) project has links to an indoor VR training system (European Space Agency, 2019; Maelstrom, n.d.), whereas the Counter-Mine Augmented Reality Training System (CMARTS) adapts an AR training system (Maurer, Cook, & Graybeal, 2019). Despite these efforts, the trainees’ evaluation of these technologies are largely unknown, in terms of training effectiveness. Thus, the current paper’s purpose is to assess participants’ performance and reaction from a pilot study, along with a cost-benefit analysis, of two recently developed simulation trainers for the Minehound handheld detector: an AR solution and a VR solution.

Training Effectiveness Evaluation

The evaluation incorporates the two initial stages of Kirkpatrick’s training effectiveness evaluation model: reactions and learning (Kirkpatrick & Kirkpatrick, 2006). Typically, the reaction component assesses the trainees’ perception of the training; this effort incorporates workload as an element of reaction, to inform the evaluation. Workload is the amount of allocated resources a trainee applies to a task. Workload adds an additional dimension to objective performance: for example, experimental and control groups may be identical in performance, but differing in workload. Here, the group with the higher workload has an additional cost or sacrifice. In other words, workload may elucidate how much resources were used to reach a level of performance. Other reactions include the user’s opinion of the devices through open-ended and close-ended questions. In terms of the learning component of the evaluation, performance changes relevant to knowledge of the Minehound device and to skill in Minehound operation are addressed.

IED Detection Task

Within the AR and VR Minehound trainer, the Warfighter has the opportunity to practice the IED detection task. Specifically, for the AR trainer, the Warfighter practices sweep form, marker placement to outline the shape of a potential mine and dig to reveal the buried object. During this process, the AR Minehound device mimics the traditional Minehound device. The VR Minehound trainer incorporates an avatar representing the correct sweep form. The VR Minehound trainer also provides an indirect form of instruction on the tablet presented on a tablet with an Android operating system. Additionally, the VR system contains a mini-game designed to place makers to outline the shape of the object as well as reveal the type of object. Unlike the AR system, the VR system asked the Warfighter to classify the detected object.

Testbed: Minehound Training Technologies

The AR and VR Minehound training devices comprise hardware and software components. Both the AR and VR devices employed the same computer platform (see Table 1).

Table 1. Testbed Computer Specifications

Make/Model	Asus Zenpad Z-10
OS	Tablet: Android 6.0
Display	9.7" LED Backlight Touchscreen LCD Panel QXGA (1536 x 2048)
Computing Processing Unit	Qualcomm® MSM8956 Hexa Core, 1.8 GHz
Graphics	Andreno 510
Memory	3GB LPDDR3
Storage	32GB eMMC

AR Minehound Analogue Equipment

The AR Minehound training platform was designed to replicate the original device (see Figure 1a). Internally, the AR Minehound device was reinforced with a 2x4 ft wood base and a steel bar placed through the handle. To increase the functional fidelity of the Minehound, metal weights and a larger battery pack were added to the physical design. A 3D printer also allowed physical and functional fidelity. The printer was designed with a dual-head extruder to provide a strong and inexpensive mold for the Vallon Metal Radar 2nd Generation (VMR2). The VMR2 was the operational Minehound system simulated for this study. A biodegradable Polylactic Acid substrate was selected to extrude the main body of the VMR2, since the substrate was less prone to warping during the 3D printing process. To increase the ductility and reliability of the sliding arm support, a common thermoplastic, acrylonitrile butadiene styrene was chosen, since this thermoplastic allowed for greater flexibility. Figure 1b shows the 3D-printed parts for the AR device.

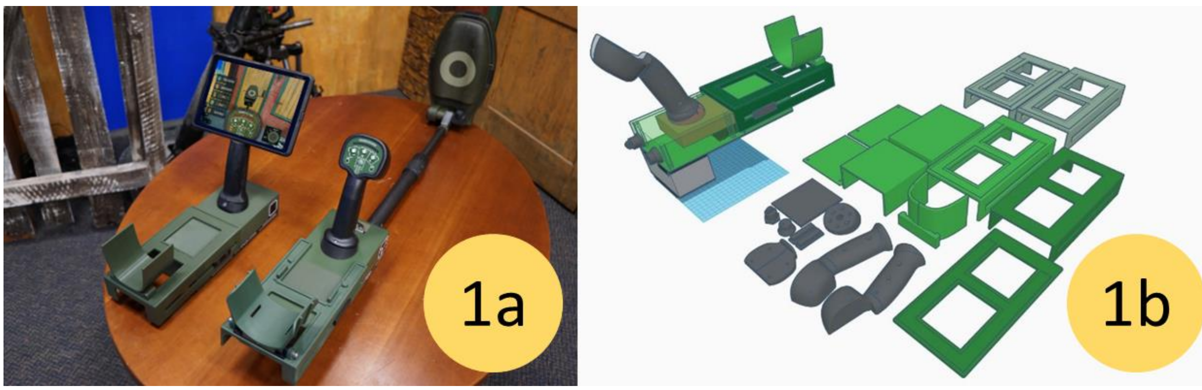

Figure 1a & 1b. 1a Illustrates a physical component of AR MH Device (Left) and the Traditional MH (Right); Figure 1b shows the 3D-printed Components

AR Minehound Software

In support of simulating the physical component of the VMR2, an AR software component was implemented to allow high-precision tracking of the Minehound device. A technical market survey of open source and commercially available pose-estimation software was completed (Reed, Eifert, Reyolds, Hillyer, & Hoayun, 2017). Based on its performance on mobile devices, a commercial pose estimation system originally developed by Qualcomm called Vuforia was leveraged.

The core Vuforia fiducial tracking was optimized by embedding fiducial markers (i.e., cues for the AR Minehound system to produce soil) within images that were native to the Minehound domain. Geospecific texture photographs are merged with repeating detectable edge elements to implement swing tracking that is accurate to a few centimeters. Real photo-textures captured at the Ft. Benning Lawson Minehound Range training area simulated a traditional lane and simultaneously served as a high-quality tracking marker. Using pose estimation, the speed of the change in position was measured and compared against the suggested speed of the real Minehound during employment. Visually, a set of dynamic arrows rendered over the AR display informed the user when the Minehound exceeded suggested linear and angular velocities during sweeping. Figure 2 shows screenshots of the AR MH device. The AR system focuses on identifying the IEDs, which are integrated with a real-world mat. Cumulatively, the AR system components comprised of a 3D-printed armrest, a tablet, fiducial markers (i.e., mats), and optional headphones.

Figure 2. AR Screenshots as seen on the tablet: Calibration (Left) and Employment (Right)

VR Minehound Software

The Unity game engine (version 5) was selected as the development tool for the virtual environment, because of Unity's high-quality graphics, portability, and ease of development. The software developers ported an existing application provided by the Army Research Lab's (ARL's) Sensor and Electronics Directorate (SED). The SED application was written in a Python programming language variant called Pygame, for PCs lacked VE capabilities. The SED software was overhauled by completely reimplementing its basic simulation capability in the Unity Game engine before adding VE components. The research team implemented an avatar that illustrated how to clear the lanes. Specifically, an Army Master Trainer from Joint Improvised Explosive Device Defeat Organization (JIEDDO) performed a Motion Capture (MOCAP) of the precise movements (from device calibration to high precision sweep techniques) to clear a lane. A subject matter expert provided a visually accurate demonstration as an exemplar, for positive training transfer. The virtual environment also contained training ranges that were recreated from Ft. Benning, Georgia; and Camp Blanding in Starke, Florida. A custom-built man-wearable photogrammetric system was developed to assist in recreating the real training ranges. The man-wearable system captured geospecific terrain, having a high-resolution of 10 cm in spatial correlation and 3 cm image accuracy. Further, to accurately simulate the audio sound of the traditional Minehound, live audio was captured during IED practice training at Lawson Army Airfield, Ft. Benning, Georgia. The sound was imported into the simulated virtual environment scenario for IED detection training. Figure 3 shows an example of a real lane and screenshots of the virtual environment.

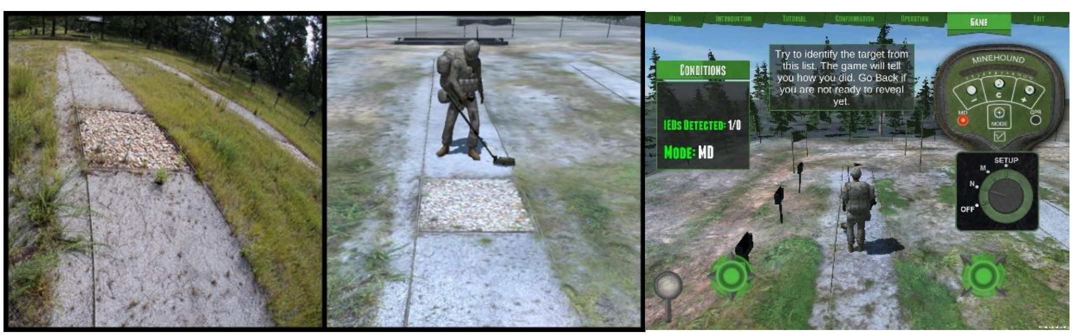

Figure 3. Lawson Army Airfield, Ft. Benning, Georgia (Left); Pictures from VR Minehound Screens (Middle, Right)

METHOD

Participants

Based on schedule availability, ten Warfighters from Ft. Benning, Georgia participated in the pilot study. To participate, each participant had to be a U.S. citizen, be 18 years or older, and have normal or corrected-to-normal vision. All participants were junior enlisted Warfighters with approximately one year of experience in the military and were males with an age range of 19 to 24 (M = 20.4, SD = 1.78). The ten participants were randomly assigned to either the experimental or control condition. The demographics questionnaire revealed that no Warfighter had Minehound detector training or counter-IED experience. Following the study, each Warfighter received a small token (under $20) for his time and effort.

Experimental Design

The pilot study comprised a between-subjects design with one independent variable, technology type: either the experimental technologies (i.e., the AR and VR Minehound trainers) or the traditional, control technology (i.e., the traditional Minehound trainer) were given. The dependent variable comprised the metrics of subjective user reactions and objective performance measures. The Minehound training instruction was abridged from the traditional training method, where the groups differed on the hands-on training device.

Metrics

The objective measures of performance were post-training IED detection accuracy, false-positive detections, pre- and post-test multiple-choice scores; and pre-to-post increases in multiple-choice scores. Post-training IED detection accuracy was calculated by dividing the number of correct IED detections (or the number of correctly flagged targets in a real-world scenario) by the number of total possible detections, expressed as a percentage. False-positive detection was calculated by the number of incorrectly identified targets. The pre- and post-test comprised 20 multiple-choice questions on how to operate a Minehound device. Both pre- and post-test questions were identical. The difference between pre-and-post test scores was divided by 100 to help calculate the percent increase.

The subjective measures of participant reactions included workload (i.e., NASA-TLX), an open-ended survey, and a closed-ended survey; the latter two surveys were created by the Minehound instructors. The workload survey, or NASA-TLX, measures a user's perception of workload. The workload measure was divided into six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration. Each subscale was rated from 0 (very low) to 100 (very high), except for the reverse-scored performance subscale. A global demand score was also calculated by averaging all six subscales. In the open-ended survey portion, participants evaluated the AR and VR Minehounds, whereas in the close-ended portion participants rated survey questions using either a 5-point Likert scale (e.g., from extremely easy to extremely difficult) or a not-applicable option. The open-ended and close-ended surveys' contents are detailed in the results section.

Equipment

Regarding the traditional Minehound group, two VMR2 Minehound, dual-sensor-detectors were used to identify IEDs using both the Metal Detector (MD) and Ground Penetrating Radar (GPR) detection modes. GPR sends a radio frequency that penetrates the ground to detect underground objects and shows disturbances in ground density, such as plastic or rock. The VMR2 kit is comprised of test pieces, batteries, a charger, cables, a belt, a headset, manuals, and the VMR2 device.

Regarding the experimental Minehound group, VR and AR Minehounds were used to identify (simulated) IEDs using both the MD and GPR detection modes. For the VR portion, five VR Minehound devices were used to train IED detection. The VR Minehound comprised a tablet and optional headphones to train IED detection. For the AR portion, five AR Minehound devices were used to train IED detection. The AR Minehound comprised a 3D-printed armrest, a tablet, fiducial mats, and optional headphones.

Procedure

The pilot study occurred over a two-day period at Ft. Benning, Georgia. On the first day, an instructor gave a PowerPoint overview of AR and VR. Next, an experimenter administered the demographics questionnaire and the pre-test. Following the completion of the questions, PowerPoint instruction was given on Minehound fundamentals. Then, the experimenter randomly assigned the ten Warfighters to either the traditional training (i.e., the control condition) or the experimental training (i.e., trained via the VR first, then via the AR second); thus, five Warfighters were placed in each group. Thereafter, each group of Warfighters spent the rest of the day training to identify IEDs using the assigned Minehound device (i.e., the traditional or VR). Note, on the first day only VR was given within the experimental training. The VR experimental training was delivered first because of the length of the instructional presentation and the need to match the traditional training learning objectives. One instructor held the traditional training outside, and one instructor led the VR training in a classroom.

On the second day, all Warfighters gathered at a classroom for PowerPoint instruction, and continued learning Minehound fundamentals. Following the lecture, the groups followed their pre-assigned order and divided into the traditional and experimental groups. One instructor held the traditional training class outside while the experimental group trained using the AR Minehound at the classroom location. Following the IED training session, the two groups completed the post-test. Next, all Warfighters were asked to participate in the live training test, which mocked a field setting with a stretch of earth, or lanes, populated with IEDs. Each Warfighter was randomly assigned to one of the three live lanes. Each Warfighter was asked to complete the IED test using the traditional Minehound. The Warfighter used the Minehound to locate the targets (i.e., buried IEDs), and used markers to identify target locations, for the full extent of the lane. After clearing the lane, a subject matter expert rated the Warfighter's IED detection accuracy, and the Warfighter completed the workload survey. Following the completion of the workload survey, the instructor provided performance feedback to the Warfighter, as an After-Action Review (AAR). At the conclusion of the live test, the Warfighter completed the open-ended and close-ended surveys about the Minehound. After that, the Warfighters were thanked, debriefed, and dismissed.

RESULTS

During the pilot study, data points were collected from the sample of ten Warfighters. The raw data was organized and remained untransformed for data analysis. Due to the small sample size, descriptive statistics were conducted to examine any trends in the data set.

Post-Test Detection Accuracy and False Positive Detection

The total group reported an average percentage score of 62.33 for post-test IED detection accuracy. The traditional group reported an average percentage score of 64.33, whereas the experimental group reported 60.33 for post-test IED detection accuracy. The number of false positive detections (i.e., instances where the Warfighter erroneously reported an IED) ranged from 0 (lowest) to 6 (highest). Within the traditional group, the highest number of false positives reported was six; whereas the experimental group reported four.

Pre-to Post-Test Multiple Choice Scores

Table 2 highlights the pre- and post-test average scores, as well as increases of scores, in both raw and percent scores of correct answers from the multiple-choice questions.

Table 2. Minehound Multiple-choice Scores

Minehound Multiple Choice Questions	Total Group	Traditional Group	Experimental Group
Pre-Test Average Score	7.5 (37.5%)	7.8 (39%)	7.2 (36%)
Post-Test Average Score	9 (45%)	9 (45%)	9 (45%)
Pre-to-Post-Test Score Increase	1.5 (7.5%)	1.2 (6%)	1.8 (9%)

Workload (NASA-TLX)

The six workload subscales, along with global demand, were calculated using mean scores; Table 3 shows the mean scores between the traditional and experimental groups.

Table 3. Post-Training Workload (NASA-TLX) Scores

Workload Subscales	Traditional Group	Experimental Group
Mental Demand	36.5	68.5
Physical Demand	32.5	55.5
Temporal Demand	27.5	45.5
Performance	59.5	49.5
Effort	48.5	72
Frustration	34.5	51.5
Global Demand	39.8	57.1

Open-ended and Close-ended Surveys

Figures 4 and 5 show the responses to the close-ended survey statements 1 and 2, respectively: "Using the Minehound Simulator was…" and "Manipulating the Minehound Simulator Controls was….". Figures 6 and 7 correspond to close-ended survey statements 3 and 4, respectively. All statements assessed the user's perception of the Minehound.

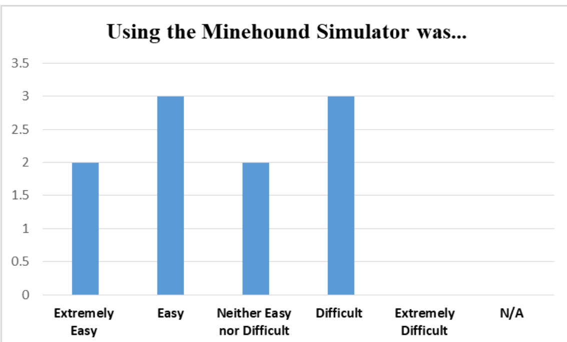

Figure 4. Survey Statement 1 Results

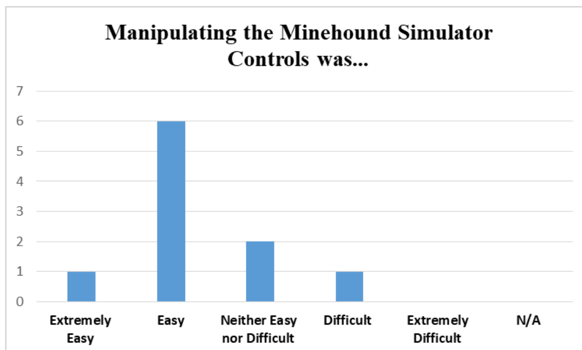

Figure 5. Survey Statement 2 Results

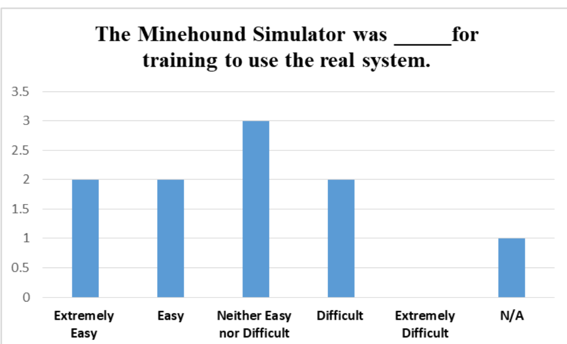

Figure 6. Survey Statement 3 Results

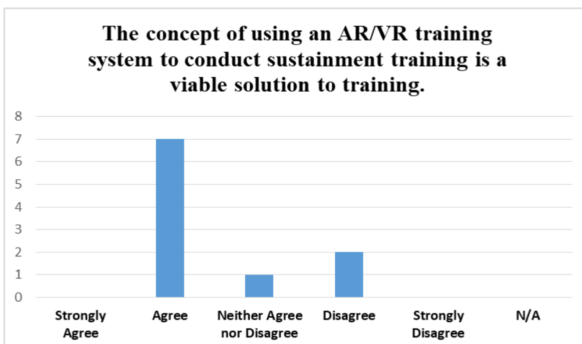

Figure 7. Survey Statement 4 Results

Questions 5 and 6 were open-ended and focused on the potential improvements and generalizability of the AR and VR Minehound simulations. Specifically, question 5 investigated ways to improve the Minehound simulations: participant recommendations emphasized better calibration function, more realistic VR scenarios, updated software, and an additional Minehound set-up process (e.g., installing batteries) identical to the real Minehound. Question 6 inquired into other applications that could generalize from the Minehound simulations: participants suggested that radios, VR room-clearing exercises, land-navigation training, combat lifesaving courses, and Nett Warrior training can all benefit from similar types of training simulations. Statement 7 asked the participant whether the Army should continue to pursue the concept of AR and VR training to maintain proficieny on actual systems. The majority of participants agreed that the army should continue to use AR and VR training to improve efficiency and to supplement live training.

Cost-Benefit Analysis

Currently, the production cost of a surrogate Minehound training device is estimated at less than $500 per unit, compared to the traditional Minehound's cost of $20,000 (Reed et al, 2017). The use of AR and VR Minehound devices provides advantages in comparison to traditional training ranges, including reduction in maintaining specialized soil types, supplying a variety of IED targets for IED training, and reducing travel time allocated to sites. Further, both devices increase accessibility to Warfighters, and the AR Minehound offers built-in After-Action Reviews (AARs).

Introducing AR and VR Minehound surrogate training devices can reduce costs associated with traditional IED training. Premium IED training ranges, such as the installations near Spesutie Island at Aberdeen Proving Grounds, offer multiple training lanes with a variety of soil types. A modern, multi-lane, IED training range was constructed at Camp Pendleton, with an initial cost of $9.2 million (Rusavskiy, 2009). The AR and VR Minehound training systems reduces the need for maintaining specialized soil types and physical scenarios, since both can be simulated. Both the AR and VR software components can be rapidly reconfigured to add new soil conditions through simulation methods. For example, the Lawson range at Ft. Benning has a single soil type, but the AR and VR Minehound applications can inject multiple levels of mineralization. As a result, the Warfighter can configure the Minehound application settings to alter soil type, and then virtually train in conditions that would be costly to implement using traditional methods.

Current IED training ranges contain a variety of buried IED targets. The construction, manual burial, and subsequent maintenance of faux IEDs are costly in terms of manpower, and potentially hazardous to the environment as caustic components (e.g., cadmium batteries) are used in the faux IEDs. With technological advancements, IED objects can be rapidly modeled in 3D software (e.g., AutoCAD and Autodesk Maya) and presented in the Minehound surrogate software. Additionally, the introduction of the AR and VR Minehound devices can reduce the time that IED instructor is required for sustainment training events. According to the General Services Administration (GSA) schedule, a single week-long trip from Ft. Leonard Wood to Ft. Benning costs a minimum of $1000 per individual (General Service Administration, n. d.). Travel budget considerations can be reduced by using the AR and VR Minehound training devices in lieu of expensive trips to remote training range locations.

The AR and VR Minehound devices were designed to promote training accessibility in both indoor and outdoor settings. The use of the Minehound device offers the Warfighter the ability to train to detect IEDs at any given point in time. Time lost for training due to environmental considerations (e.g. rain days/wet bulb globe temperature; United States Army, 2016) can be prevented by using the Minehound training device indoors. Further, the AR and VR enabled Minehound devices provide an objective performance evaluation, which can assist the instructor with grading. As a result, the instructor can actively engage with the Warfighter on overall technique rather than monitor each trainee's instantaneous progress.

Finally, the AR Minehound device offers the Warfighter the ability to conduct individual AARs. The AAR pinpoints the exact movements where the Warfighter swept and cleared. Additionally, the review highlights areas of the virtual range that were not properly cleared during the training session. The Warfighter can learn from their errors and discuss ways to improve. The AAR setting of the AR Minehound device is designed to provide real-time sweep-speed feedback. This AAR capability is not currently available at most ranges; still, similar AAR in the real-world would require a sonar-based instrumented system appended to advanced training environments. The AR Minehound device can be considered a cost-effective alternative to the sonar-based system for AARs.

DISCUSSION

This discussion will focus on the integration of the performance and survey data to explain current trends for the Minehound system. A closer look at the false positive detection scores revealed that the experimental group made fewer mistakes compared to the traditional group. Perhaps, the experimental group placed greater attention to the detection task and therefore, lowered the chances of human error (i.e., changing perception towards simulation). Perhaps, the simulation provided a level of serious gameplay. Further observation is required to determine if this research statement is confirmed.

Next, the results showed marginal differences between post-test detection for the experimental and traditional groups. Although no inferential statistics were conducted, the current trend indicates a less-than five-point difference between each post-test score. Further, the initial results indicate a consistently higher workload in the experimental condition. Although the task challenge was high, the participants were not disengaged, as evident in similar performance scores. The higher workload scores suggest increased use of resources were required to sustain a level of performance approximate to the control group. The increase in workload indicates a sense of value of striving to perform well using the AR and VR Minehound devices. The usability findings indicate that the Warfighter generally favored the use of simulations (stemming from close-ended questions 1 and 2), and the reception to using the simulation as preparation for the real Minehound was mixed (stemming from close-ended question 3). The usability results start to show the openness to using simulation for training of Minehound detection tasks. Furthermore, the most consistent rating comes from the use of AR and VR as a means of sustainment training, which suggests that the acceptance of simulated systems has a role in training Minehound detection tasks.

The increase in workload experienced by the experimental group may be attributed to the familiarity of the system. The experimental group was unfamiliar with the traditional Minehound system during the live lanes post-test. The switch between systems may have cost additional workload, due to lack of fidelity (i.e., realism) afforded from the experimental training. The participants trained using the AR and VR Minehound systems, which emphasized the fantasy element related to dying; by showing a Warfighter avatar exploding when walking over an explosive, the jeopardy of dying may have been taken lightly. Perhaps, the AR and VR Minehounds can be enhanced from an instructional standpoint: a cue-based system may be used to reduce load within the training phase, such as for improving sweep form. Cues are a method to orient visual attention towards relevant material. In a sense, they act as built-in instructors. For example, temporal demand was lowered in a signal detection task by highlighting, or drawing attention to, target cues (i.e., training material; Salcedo, Lackey, & Maraj, 2016). In terms of sweep form, the present AR presented arrows noting irregular sweep velocity, and presented an optional After-Action Review of correct sweep speeds (cued by different colors); the VR presented a vicarious third-person view of correct sweep form via an avatar. A more salient cue system may be needed.

Within the multiple-choice scores, both groups showed an increase in scores from pre-test to post-test. The experimental group increased slightly from pre-to post-test, but both conditions' post-test scores were equal. Here, the data trends suggest that the experimental group had comparable scores to the traditional group; this outcome provides support of the experimental IED training. Although, the post-test scores indicated low scores for both groups, the focus of the paper was not to determine the post-test scores themselves, but how they compared between groups.

The performance and reaction components add another consideration to the provided cost-benefit analysis. Ultimately, it seems there was a stronger match in performance than the match of workload between training paradigms. These issues must be incorporated with other concerns, such as traditional training time and cost. Although the idea of using AR and VR as sustainment training is well-received, further tweaks in system design may be needed if one wanted to match traditional training outcomes to AR and VR training outcomes during the initial stages of the Minehound training continuum.

LIMITATIONS

The pilot study has two notable limitations. The first limitation was the data collection protocol made no distinction between the VR and AR groups, which limited the research analyses for causal inferences between the different experimental conditions. The next iteration of the research study would benefit from isolating the experimental conditions to a VR group and an AR group. The second limitation is the number of research participants. A sample of 10 participants limits the inferential statistics to reliably assess the effectiveness of the Minehound training device. Future experiment may benefit from implementing suggestions derieved from the open-ended responses. For example, improving the instruction through more realistic VR scenarios, better calibration function, and installing batteries as a part of the set-up process.

CONCLUSION

The present paper investigated a pilot of VR and AR technology for counter-IED detection. The motivation for the evaluation of the Minehound simulation was to improve the current Minehound training paradigm and to ultimately save lives. Various lessons were learned from the data. In terms of a pilot investigation, performance and reaction to the training was measured. The multiple-choice aspect of effectiveness was equal in post-test scores, supporting the focus of the experimental training as an additional layer of simulation. The detection accuracy score, or practical training aspect of effectiveness, was somewhat similar between groups. The similar performance outcomes indicate that the simulation may be implemented, but may not provide a significant increase over traditional training. However, workload was higher in the experimental group: complete disengagement was not reached, but rather an extra cost of workload may have been introduced to meet the same performance as the traditional group. It is unclear what factors (e.g., fidelity or instruction) attributed to the increase in workload. Regarding the survey reponses, the users viewed the concept of AR/VR simulation as an acceptable tool for sustainment training.

The next steps for this research initiative include 1) increase sample size in order to conduct statistical analyses, such as parametric or non-parametric tests; 2) verify the initial trends in the data; 3) make a distinction between the three conditions to determine the effectiveness of the Minehound training devices, 4) determine the origin of workload within the experimental conditions, and 5) provide an interface training for particiants to get acquainted with the technology. In summary, this paper builds a foundation for understanding alternative training approaches for hand-held IED detectors.

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